
3.2 Project Operations

This section provides an overview of the operational activities involved in removing, treating, and stabilizing the V-Tank waste. Prior to operations, equipment/system testing and training will be completed as described in section 3.4.8. Mobilization of equipment for operational start up activities and a management self-assessment (MSA) will then be conducted.

At the completion of the MSA, tank content preparation, waste treatment, stabilization, disposal, demobilization, and area cleanup operations will be performed.

3.2.1 Mobilization of Equipment

Prior to beginning treatment operations, equipment and trailers will be staged and readied. Major equipment (trailers, skids, above ground storage tank, etc.), will be staged as identified in the layout plan (see Appendix C, Drawings C-1 and C-2). Temporary containment tents will be set up and spare parts for key components including hoses and connections will be identified and purchased.

550 55-gal drums of sodium persulfate (an oxidizing agent used in the chemical oxidation process) are anticipated to be stored intermittently at TAN-628 depending on available storage space at the time of receipt. Other storage options for the persulfate that are anticipated to be available are TAN-607-A, TAN-603, or possibly cargo containers. The 55-gal drums will be loaded on pallets and stacked two pallets high. Intermediate storage of other chemicals used in the oxidation process (nitric acid, sodium hydroxide, and hydrogen peroxide) will be determined at the time of receipt.

Monitoring equipment (including a video monitoring system) and sampling stations will be staged and setup as part of mobilization. This system will include.

- Control/Data logger System
- Video camera
- Control trailer leads

An Emergency response station will also be staged including:

- Eyewash station (temperature controlled)
- Fire extinguishers (inspected)
- First Aid Kit (inspected)
- Spill Kit
- Drinking water
- Clear signage

Personnel safety zones, barriers, and postings will be established and an equipment safety walk down will be conducted prior to startup. Once operations begin, safety walk downs will be performed daily.

3.2.2 Management Self Assessment

At a minimum, a management self-assessment will be completed prior to beginning operations. A readiness assessment or an operational readiness review may be required by facility management and will be determined at a later date. The management self-assessment checklist is included in this report as Appendix E.

3.2.3 Tank Preparation

A vacuum excavator and air lance will excavate down to the surface of each of the TSF-09 tanks (V-1, V-2, and V-3) and create a 2-foot diameter hole allowing operations personnel to connect a 12-inch casing pipe to the top of each tank in an area free from piping. A core drill will then be lowered through the casing pipe and drilled through the sealant and the tank wall. An 8-inch sump access pipe will be lowered into the tank through the 12-inch pipe casing and the newly drilled hole (see Appendix C, Drawing C-4). This access method was chosen over a sloped excavation or shored excavation to allow close proximity operations next to the tank, minimize unanticipated encounters with underground lines, and provide tank access after operations. A peristaltic pump will be connected to the sump access pipe (see Figure 6).

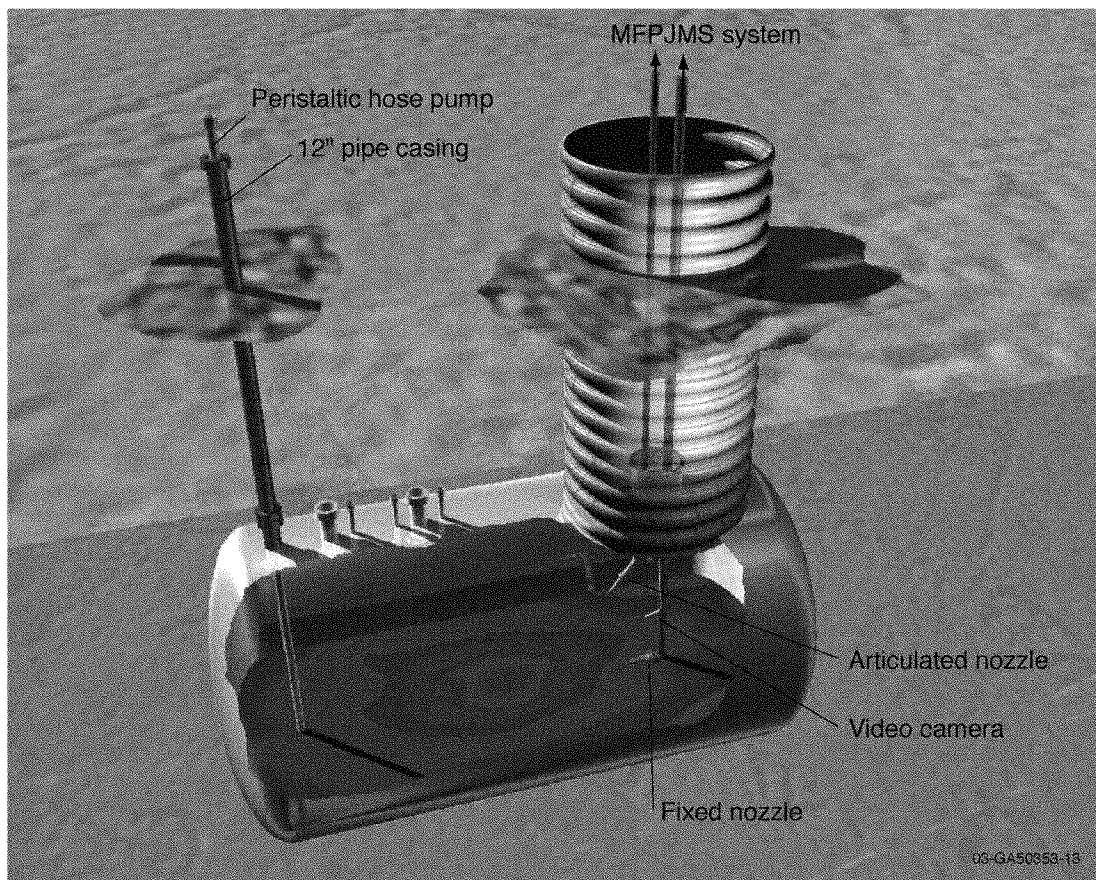


Figure 6. The TSF-09 tanks will be accessed through a pipe casing and a manway.

The MFPJMS will be the primary means of conveying tank waste between tanks and to the reaction vessels and the grouting/stabilization system. However, the MFPJMS cannot remove all the waste in a tank, including the residual waste that collects in the tank sumps. A peristaltic pump will be used to remove the remaining waste.

The 20-inch manhole flange for each of the TSF-09 tanks (V-1, V-2, and V-3) will be removed as needed. An equipment tool fixture will be installed on each tank. MFJPMS piping will be inserted into each tank and anchored to the equipment tool fixture. Sludge removal piping will be connected to the MFJPMS. A camera system (used during the waste removal process to determine if the waste has been successfully removed) will be installed and connected to allow for observation during operations.

Each of the TSF-09 tanks has a 3-inch vent line. The cap on all three vents will be removed and a flexible hose will be attached to the vent line and routed to the off gas system. This hose will draw a negative pressure in the tanks that will cause outside air to flow into the tanks, decreasing the potential for contaminated particles escaping into the atmosphere. Monitoring equipment (cameras, lights, etc) will be tested and the chemical additive system will be filled.

3.2.4 Tank Consolidation and Waste Treatment

The waste in the V-Tanks will be consolidated and homogenized prior to oxidation in order to produce a consistent waste feed to the oxidation process. This consistent feed will enhance routine operations of the oxidation process. A reasonable worst-case approach was taken to develop operational parameters based on limited blending capabilities. This approach limited the consolidation and homogenization effort to the combination of V-3 and V-1 and the combination of V-9 and V-2. More optimal homogenization and consolidation efforts would decrease the complexity of the treatment plans. The title design of the treatment process should take into consideration the goal of creating just one consolidated homogenous waste stream.

One of the benefits of tank waste consolidation is that the TSF-09 Tanks (V-1, V-2, or V-3) may be used as treated waste storage tanks. As each tank is emptied and flushed, that tank becomes a storage tank for the treated waste from the next tank. This waste treatment and transfer methodology is shown in Figure 7. This method takes advantage of the empty tanks and allows treatment operations to continue while awaiting sampling results. In addition, because storage is underground, radiation exposure is minimized and freeze protection is not required.

In order to facilitate the treatment and transfer operations, approximately 6000 gallons of supernate (water above the surface of the sludge) will be removed from V-3 prior to consolidation and homogenization efforts. This water will be used to flush the tanks, as makeup water for chemical additions to the treatment process, and as rinse water for decontamination of empty tanks and process equipment. In addition, the supernate may be used to assist in the resuspension and pumping of chemically-oxidized waste from the underground tanks, as it is mixed with grout. Until the results of the demonstration tests are complete, it is difficult to project exactly how much water will be needed for each step. The numbers used in this report reflect the best judgment at this point. This water will be stored in the AGTST. While most of the contaminants requiring treatment are located in the sludge phase of the waste, this water will still be run through a granulated activated carbon (GAC) bed prior to its use to prevent the re-introduction of hazardous organic contaminants to treated waste. As the water may still contain metals or radionuclides, any left over water will be solidified prior to disposal.

Tank consolidation will entail four operations. First, about 6000 gallons of supernate will be pumped from V-3 to the AGTST. Second, the waste from V-9 will be consolidated into the V-2 Tank and V-9 will be rinse and cleaned. Third, Tank V-3 will be consolidated into Tank V-1 and V-3 will be rinsed and cleaned. Finally, the supernate in the AGTST will be pumped into V-3.

Figure 7 shows the ES-CO/R/S process flow beginning with the removal of the supernate from V-3. The tank consolidation (steps A, B, and C in Figure 7) will take place in FY 2004 to facilitate early progress. The tank contents will remain consolidated in the V-Tanks until FY 2005, when the oxidation/reduction and stabilization steps (D-I) of the project will begin. A remainder of this section provides a description of each step in the process.

V-Tank Transfer Diagram

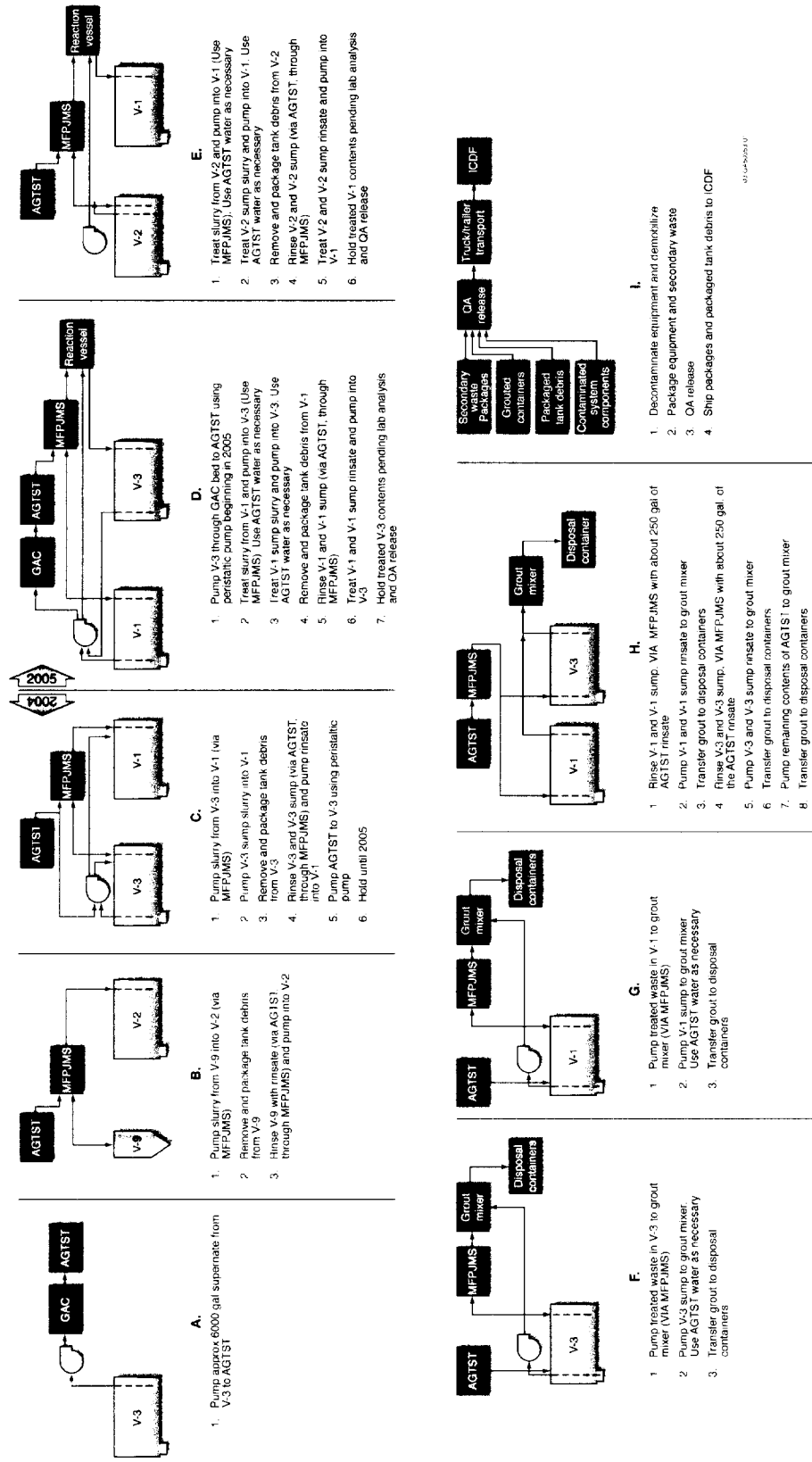
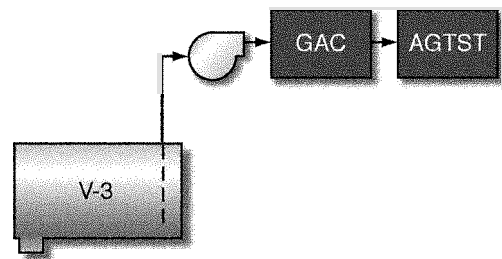


Figure 7. ES-CO/R/S Process Flow.



Step A – Tank Preparation. About 6,000 gal of supernate from Tank V-3 will be pumped through a granulated active carbon (GAC) bed into the AGTST. A Watson-Marlow SPX 40 peristaltic hose-pump, equipped with a particulate filter, will pump the supernate at a rate low enough to ensure the sludge, laying below the supernate, does not get disturbed and entrained in the decanted liquid. The suction line from the peristaltic pump will be rigidly fastened to an equipment tool fixture and lowered into the supernate. A flow diffuser at the end of the suction line will be used to divert the inlet flow of liquid away from the sludge layer. Figure 8 is a simplified schematic of the decanting, treatment, and containerization subsystems layout. A remote video camera will be used to visually verify that sludge is not entrained with the liquid being decanted. Access to the liquid will be through the 20-inch manhole and 6 foot diameter culvert providing access to the manhole from ground level.



A.

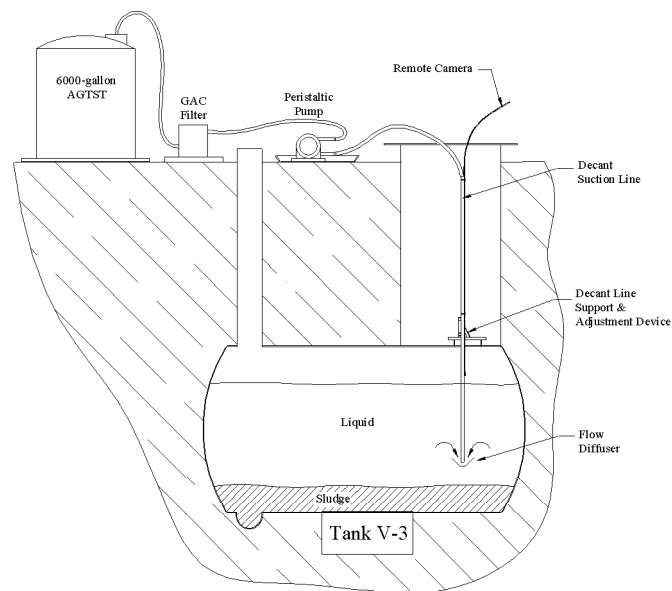
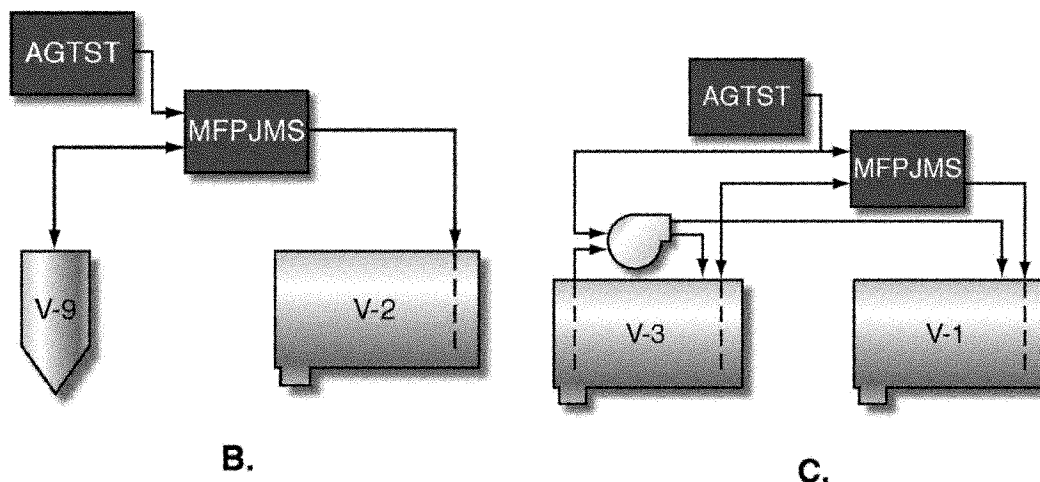


Figure 8. Supernate from Tank V-3 will be pumped into the AGTST using a peristaltic hose pump.

Steps B and C – Tank Content Consolidation. Pumping the contents from Tank V-9 into Tank V-2 and the contents of Tank V-3 into Tank V-1 will consolidate the waste from the V-Tanks.

The MFJPMS will homogenize the contents of V-9 and pump the sludge into V-2. Camera systems will be used ensure all the waste has been removed. Any debris remaining in V-9 will be removed with long reach tools and packaged for disposal at the ICDF. V-9 will be rinsed with 200 gallons of supernate from the AGTST creating what is referred to as 'rinsate'. The rinsate from V-9 will also be pumped into V-2.

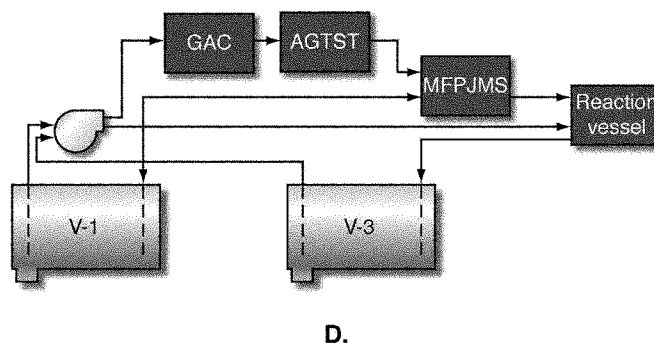


A similar process will be used to pump the contents of V-3 to V-1. The MFPJMS will homogenize the waste in V-3 and pump it into V-1. A peristaltic pump line lowered through the 12-inch sump access pipe will remove the slurry in the V-3 sump. Since the MFPJMS cannot remove all the tank contents (because the height of the nozzle opening is above the tank floor), a peristaltic pump is used to remove the remaining liquid from the sump. Any debris in the V-3 tank and V-3 sump will then be removed and packaged for disposal using long reach tools and a camera system. Tank V-3 and the V-3 sump will be rinsed with ~500 gallons of supernate from the AGTST. The rinsate from V-3 will be pumped into V-1 by peristaltic pump.

The remainder of the AGTST contents (~5300 gallons) will be pumped into Tank V-3 using a peristaltic pump for holdover until FY 2005. Steps B and C result in tank waste being consolidated into V-2 and V-1 and the supernate being pumped into V-3 for holdover until FY 2005.

Step D - Treat V-1 and Transfer Treated Waste to V-3. To begin the FY 2005 operations, the supernate located in V-3 will be pumped to the AGTST using a peristaltic pump.

The MFPJMS will then be used to mix the contents of V-1 and transfer an oxidation batch through the MFPJMS to one of the two reaction vessels. Once inside the reaction vessel, the waste undergoes the oxidation process. V-Tank waste will be oxidized using two oxidizing agents, Fenton's Reagent (composed of



hydrogen peroxide catalyzed by ferrous and cuprous iron) and sodium persulfate². Each batch of waste undergoes a treatment process that includes the addition of the two oxidizing agents, pH monitoring and control, and temperature control. A detailed description of the oxidation process, including batch sizes and calculations, is provided in Section 3.3.4.

Once a batch of waste has been through the oxidation process it will be cooled to 20°C to avoid corrosion issues (see Section 3.3.6 for information on corrosion issues with the oxidized waste). While the waste is cooling, samples of the batch will be sent for lab analysis to determine a relative completeness of reaction. Additional samples will be taken as needed. When sufficient reaction has occurred, the batch will be pumped from the reaction vessel to V-3 using a Moyno positive displacement pump to transfer the viscous waste fluid. Sufficient reaction will be comply with the LDR organic treatment standards for the final stabilized waste form.

Once a batch of waste has been oxidized the reaction vessel will be filled with another batch of waste from V-1 until all the waste from V-1 has been oxidized. Both reaction vessels will be used to treat the waste. However, only one vessel will perform oxidation at a time. This eliminates the need for two off-gas systems. The total waste volume of oxidized waste discharged to V-3 is ~7900 gallons.

When Tank V-1 is empty, the slurry in the sump will be removed using a peristaltic pump, as described in Step C. Any debris in the V-1 tank and V-1 sump will be removed using long reach tools and packaged for disposal. The V-1 tank and the V-1 sump will be rinsed with about 500 gallons of supernate and the rinsate from V-1 will be pumped into the reaction vessel for treatment. The treated rinsate will then be pumped to V-3.

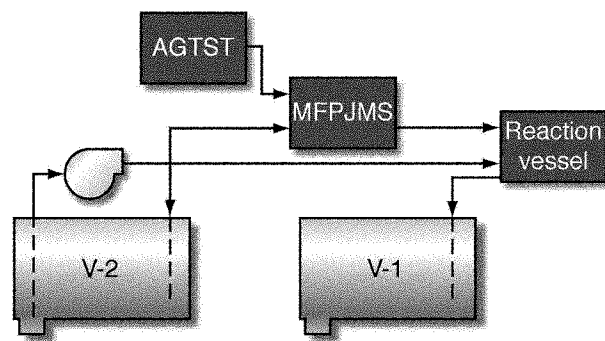
At this point, Tank V-3 contains oxidized material from the V-1 and V-3 Tanks that is ready for stabilization. The contents of V-3 will be held pending final lab analysis and QA release.

Step E - Treat V-2 and Transfer Treated Waste to V-1.

The waste in V-2 will be treated using the same oxidation process used to treat the V-1/V-3 waste. Samples of each batch of treated V-2/V-9 waste will be sent for lab analysis to determine the relative completeness of reaction. Additional samples will be taken as needed.

When sufficient reaction has occurred, each batch of V-2/V-9 waste will be pumped back to V-1 by a Moyno pump. The oxidizing process will be repeated until the contents of V-2 have been treated.

Once the entire contents of V-2 have

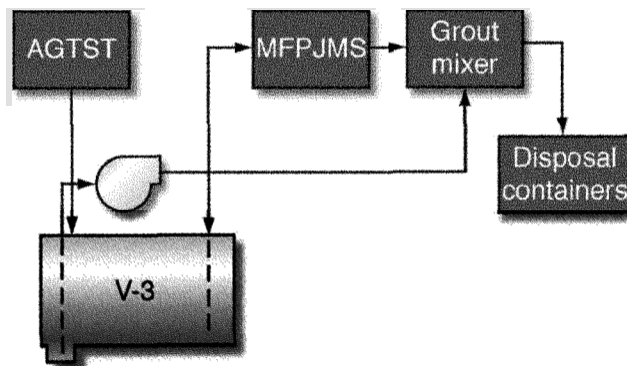


E.

² Sodium persulfate is also known as sodium peroxodisulfate. Throughout this report, it is referred to as sodium persulfate or persulfate.

been treated and transferred, V-1 will contain oxidized waste originally stored in Tanks V-2 and V-9. The contents of V-1 will be held pending final lab analysis and QA release.

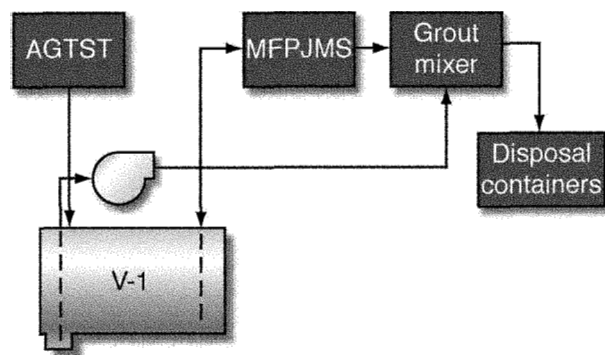
Step F - V-3 to Disposal Containers. Once the V-Tank waste has achieved demonstrated regulatory compliance through oxidation, it will be stabilized using grout. Water from the AGTST will be added to V-3 to decrease the density of the oxidized waste. The MFJPMS will mix the contents of V-3 and transfer the contents through the MFJPMS to the grout mixer and from the grout mixer to 550-gallon polyethylene disposal containers (a detailed description of the grouting process is included in 3.4.3). The 550-gallon size was chosen to minimize the number of containers and to make it easier to move the containers. Final container selection should consider the fact that some expansion of the grouted contents is anticipated. The residual waste at the bottom of the tank that cannot be removed using the MFJPMS will be pumped to the grouting system using a Moyno pump.



F.

The grout mixture will be 80% blast furnace slag, 20% type V Portland cement. This mixture provides good leachability resistance, good free-liquid binding capacity, and good resistance to sulfate attack (for a full description of the grout formulation see section 3.3.7).

The solid waste form, including grout, will be sampled and tested for disposal compliance. The disposal containers will be held pending lab analysis and QA release.

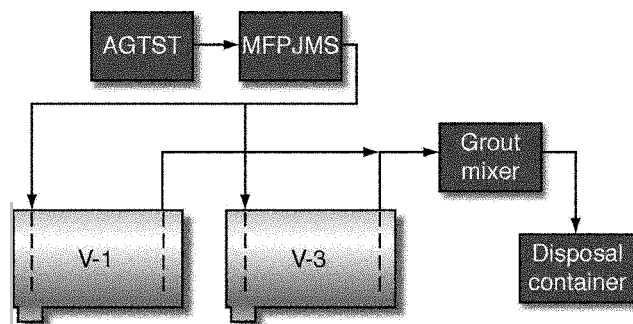


G.

Step G - V-1 to Disposal Containers.

The MFJPMS will re-suspend and mix the contents of V-1 and transfer the contents to the grout mixer and from the grout mixer to disposal containers. Water from the AGTST will be added to V-1 to reduce the density of the oxidized waste making it suspend and remove the waste from V-1. The residual waste at the bottom of V-1 will be pumped out using a Moyno grout pump. At this point, Tank V-1 will be empty.

The solid waste form, including grout, will be sampled and tested. The disposal containers will be held pending lab analysis and QA release.



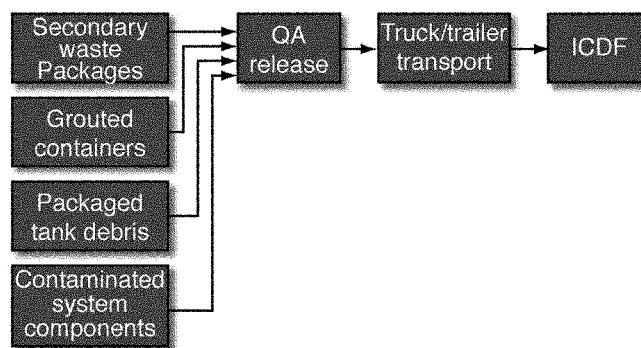
H.

Step H - AGTST Content Treatment and System Cleanout. The remaining contents of the AGTST, if any, will be used to rinse the V-1 and V-3 tanks, the MFPJMS, and the grout mixing system. The V-1 and V-3 tanks and sumps and the MFPJMS will be rinsed with about 250 gallons of AGTST rinsate each. The rinsate will be pumped to the grout mixer and transferred to disposal containers.

Step I – Demobilization. At this point the V-Tanks, the MFPJMS, the AGTST, and the grout system have been emptied and rinsed.

Upon QA release, secondary waste packages, grouted containers, packaged tank debris, contaminated system equipment will be loaded and transferred to the ICDF. The process equipment is then ready to be dismantled and demobilized.

The MFPJMS piping will be removed from each large tank (V-1, V-2, and V-3) and cleaned. The equipment tool fixture will be capped and sludge removal piping will be removed from to the MFPJMS. The peristaltic pump will then be removed and the suction line will be removed and cleaned.



I.

Major equipment e.g., trailers, skids, above ground storage tank, etc., will be disconnected, decontaminated (if necessary), and loaded. The diesel generators will be disconnected and returned. The containment structures will then be removed along with any barriers, signs, and fences. The four V-Tanks will be excavated and removed from the ground. Soils will be sampled and tested. Any contaminated (hazardous or radioactive contamination) soils will be disposed at the ICDF. All non-contaminated materials will be land-filled or surplused. The excavations will be backfilled with clean soil and the area will be leveled. The tanks will be cut up into manageable pieces and hauled to ICDF for disposal.

3.3 Chemical Process Design

The primary treatment process in ES-CO/R/S is chemical oxidation. Chemical oxidation is an ambient pressure, low temperature treatment process that uses strong oxidants to convert organic contaminants in waste to carbon dioxide, water, and halide salts. Removing organic contamination in this manner requires a chemical reaction to mineralize the contaminants. In ES-CO/R/S, this reaction takes place in reaction vessels as two oxidants: Fenton's reagent (hydrogen peroxide catalyzed by ferrous or cuprous ion) and sodium persulfate, are added to the V-Tanks waste. These oxidants initiate the oxidative reaction that removes and mineralizes the contaminants in the waste.

Following oxidation, the waste is stabilized using a specific grout formulation. The following design criteria are discussed in this section:

- The treatment standards for chemical oxidation
- The chemical oxidants being used
- A summary of the mass balance calculations performed in support of ES-CO/R/S
- The batch size designated for treatment
- The oxidation process for each batch of waste
- The consolidation, sampling, and retrieval of the oxidized waste
- A discussion of possible corrosion issues associated with the oxidized waste
- The grout formulation.

3.3.1 Chemical Oxidation

The purpose of chemical oxidation of the V-Tank waste is to remove hazardous organics from the waste allowing the waste to be stabilized and disposed at the ICDF. The degree of chemical oxidation needed for allowing such disposal is based on a combination of treatment standards as discussed later in this chapter. Table 3 provides a listing of the treatment standards for the primary hazardous organic materials in the V-Tank waste, along with the estimated concentrations of the waste expected to be present in each of the composite tank sludges that are expected to bound the final consolidated waste stream. Included in this table are estimates of the mean concentration as well as the 90% upper concentration limit (UCL) for each hazardous organic compound. Chemical oxidation needs to achieve concentrations of these hazardous organics below their respective treatment standard, after chemical oxidation and stabilization of the tank sludges has occurred. Therefore, the chemical oxidation process needs to be sufficient that the chemically oxidized waste will meet treatment standards after stabilization. Designing the chemical oxidation process around the 90% UCL concentrations gives a 90% confidence level that the chemical oxidation process will be sufficient to meet treatment standards for each of the hazardous organics, after the waste has been stabilized.

Table 3. Mean and 90% UCL Concentrations of Primary Hazardous Organics within the Bounding Composite Waste Sludges, Compared to applicable treatment standards.

Hazardous Contaminant	Composited V-1/V-3 Tank Concentration (mg/kg)		Composited V-2/V-9 Tank Concentration (mg/kg)		Treatment Standard (mg/kg)
	Mean	90% UCL	Mean	90% UCL	
Trichlorethylene (TCE)	1.5	5.6	2362	4168	6
Tetrachloroethylene (PCE)	231	380	172	196	6
1,1,1-Trichloroethylene (TCA)	0.14	0.38	289	479	6
Bis-2-ethylhexyl phthalate (BEHP)	967	1116	494	820	28
Aroclor-1260 (PCB)	31	37	34	41	10

Table 4 shows the projected mean and 90% UCL concentrations of primary hazardous organic compounds within each of the bounding composite sludges after they have been oxidized.

Table 4. Projected Mean and 90% UCL Concentrations of Primary Hazardous Organic Compounds Within the Oxidized Waste Sludges after oxidation, Compared to treatment standards.

Hazardous Contaminant	Composited V-1/V-3 Tank Concentration (mg/kg)		Composited V-2/V-9 Tank Concentration (mg/kg)		Treatment Standard (mg/kg)
	Mean	90% UCL	Mean	90% UCL	
Trichlorethylene (TCE)	0.0004	0.0014	0.5	0.8	6
Tetrachloroethylene (PCE)	0.1	0.2	0.05	0.06	6
1,1,1-Trichloroethylene (TCA)	0.0002	0.0004	0.3	0.4	6
Bis-2-ethylhexylphthalate (BEHP)	0.02	0.02	0.008	0.014	28
Aroclor-1260 (PCB)	0.0005	0.0006	0.0004	0.0005	10

3.3.1.1 Chemical Oxidants

Based on existing research, the most promising chemical oxidants for use in oxidizing the hazardous organics within the V-Tank waste are Fenton's reagent (i.e., hydrogen peroxide catalyzed by ferrous or cuprous ion), and sodium persulfate. Table 5 provides data showing the oxidation potential for both sodium persulfate and hydrogen peroxide, as well as the hydroxyl and persulfate radicals that are produced by the proposed chemical oxidations, under optimized processing conditions (i.e., controlled pH, sufficient catalyst, etc.).

Table 5. Oxidation Potential (in eV) for Various Persulfate and Peroxide Materials and Radicals.

Potential Oxidant	Oxidation Potential (eV)
Hydroxyl radical	2.76
Persulfate Radical	2.6
Persulfate	2.0-2.05
Hydrogen peroxide	1.776

After evaluating potential chemical oxidation processes, the following process has been specified pending further bench testing, field testing, and design.

- Chemical oxidation of the VOCs within the waste, using Fenton's reagent, at a temperature of 40°C
- Chemical oxidation of the BEHP, PCBs, and residual VOCs, using Fenton's reagent at a temperature of 80°C
- Chemical oxidation of the oil-phase residues, and residual VOCs, BEHP, and PCBs, using sodium persulfate at 80°C.

3.3.2 Mass Balance Summary

Mass balance tables, showing the effected change in waste composition accompanying each of the chemical oxidation processes (along with stabilization of the final chemically-oxidized waste) are shown in Tables 6 and 7, for both composite waste volumes. Included in the mass balances is information regarding the total amount of chemical oxidants, catalysts, anti-foaming agents, pH adjusting chemicals and additional water that will be needed for each step of the chemical oxidation and stabilization processes. The mass balance for the chemical oxidation process is based on the assumption that insignificant amounts of volatile materials will be sent to the off gas system, during the chemical oxidation and heating/cooling processes. For mass balance purposes, this assumption is conservatively valid, since the chemical oxidation system relies on a condenser that maintains the minuscule off-gas emissions (~ 4 scfm peak) at a temperature of 5-18°C, exiting the condenser. Included in the mass balances are 90% upper confidence limit (UCL) estimates for the important contaminants for treatment (CFTs). These 90% UCLs should be used in all calculations, to guarantee (to a 90% confidence level) that the chemical oxidation and stabilization process is sufficient to meet Land Disposal Requirements (LDR) associated with final disposal of the waste. The targeted CFTs with 90% UCLs are:

-
- Mercury
 - Cadmium
 - TCE
 - PCE
 - TCA
 - BEHP
 - Aroclor-1260
 - TRU content
 - Cs-137.

The summary mass balances show that a significant amount of sodium persulfate will need to be added to each composite sludge waste, particularly in comparison to the amount of Fenton's Reagent that is to be added to each composite sludge waste. The primary reason for this is that substantially more oil (the organic component targeted by the sodium persulfate) is expected to be present in the waste than any of the other regulated organic materials (which are to be oxidized by hydrogen peroxide in Fenton's Reagent). Another reason for the significant amount of sodium persulfate is that more oxidant (on a mole basis) is needed to oxidize the oil than the other organic materials.

This large addition of sodium persulfate increases the density of the chemically oxidized sludges from ~1.0 g/ml to ~1.76 g/ml, while increasing the waste volume by 68% or 111% (depending on the composite sludge waste). In addition, solubility calculations indicate that the final chemically oxidized waste may contain up to 47 wt% insoluble sediments, in the form of either excess sodium persulfate or sodium bisulfate. The increased density and sedimentation experienced during chemical oxidation may complicate agitation of the sludge waste, a necessary step during chemical oxidation. If needed, additional water will be added to the tank to continue sufficient agitation during the chemical oxidation process. For conceptual design purposes, however, such additional water addition is not expected to be necessary. The large volume of water added to the V-2/V-9 composite sludge stems from the fact that the total amount of sodium persulfate in the waste, at any one time, needs to stay below the total amount of water that is present in the sludge waste. If this does not occur, the sodium persulfate will also oxidize the water in the sludge. Based on detailed calculations looking at the peak level of sodium persulfate present in the waste, there is sufficient water in the V-1/V-3 composite sludge to eliminate the need for additional water to be added to this waste.

The large volume of sodium persulfate added to each waste stream may also complicate final stabilization of the chemically oxidized waste, since it has such high quantities of sulfate material, which necessitates further bench scale testing and field scale testing of the grout formulation used for stabilization. However, in order to dispose of the waste at the ICDF, the waste must meet LDRs, and remain solid (no liquids). This conceptual design assumes that a stabilized waste form, even with such high sulfate numbers, will meet all LDRs, and remain solid.

Table 6. Summary Mass Balance for the V-1/V-3 Composite Sludge Waste, During Chemical Oxidation and Stabilization Processing.

Constituent	1 2 3 4 5 6 7 8							
	Mixed Tank	Contents Oxidize	VOCs Oxidize	SVOCs Oxidize	Oils Init.	V-1 Rinse	Init. Stab.	Resusp. Rinse
Inorganics	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Aluminum (Al)	6.72E+02	6.67E+02	6.56E+02	2.24E+02	2.16E+02	1.42E+02	1.82E+02	1.07E+02
Antimony (Sb)	8.33E-01	8.26E-01	8.13E-01	2.77E-01	2.75E-01	1.81E-01	2.66E-01	1.56E-01
Arsenic (As)	4.80E-01	4.76E-01	4.69E-01	1.60E-01	1.54E-01	1.01E-01	1.30E-01	7.63E-02
Barium (Ba)	6.72E+00	6.67E+00	6.56E+00	2.24E+00	2.16E+00	1.42E+00	1.83E+00	1.08E+00
Beryllium (Be)	1.07E+00	1.06E+00	1.04E+00	3.56E-01	3.44E-01	2.25E-01	2.89E-01	1.70E-01
Cadmium (Cd) (mean)	3.04E+00	3.02E+00	2.97E+00	1.01E+00	9.78E-01	6.41E-01	8.23E-01	4.82E-01
Cadmium (Cd) (90% UCL)	4.01E+00	3.98E+00	3.91E+00	1.34E+00	1.29E+00	8.44E-01	1.08E+00	6.35E-01
Calcium (Ca)	1.88E+03	1.86E+03	1.83E+03	6.26E+02	6.05E+02	3.97E+02	5.17E+02	3.03E+02
Chlorides (Cl)	1.22E+02	5.26E+02	5.37E+02	2.06E+02	2.01E+02	1.32E+02	1.82E+02	1.06E+02
Chromium (Cr)	2.44E+02	2.42E+02	2.38E+02	8.13E+01	7.84E+01	5.14E+01	6.60E+01	3.87E+01
Iron (Fe)	3.95E+03	4.26E+03	4.19E+03	1.43E+03	1.38E+03	9.05E+02	1.16E+03	6.81E+02
Lead (Pb)	4.06E+01	4.03E+01	3.96E+01	1.35E+01	1.30E+01	8.56E+00	1.10E+01	6.44E+00
Magnesium (Mg)	2.78E+03	2.75E+03	2.71E+03	9.25E+02	8.92E+02	5.85E+02	7.53E+02	4.42E+02
Manganese (Mn)	8.57E+02	8.50E+02	8.36E+02	2.85E+02	2.75E+02	1.81E+02	2.32E+02	1.36E+02
Mercury (Hg) (mean)	5.80E+01	5.75E+01	5.66E+01	1.93E+01	1.86E+01	1.22E+01	1.57E+01	9.18E+00
Mercury (Hg) (90% UCL)	6.67E+01	6.62E+01	6.51E+01	2.22E+01	2.14E+01	1.40E+01	1.80E+01	1.06E+01
Nickel (Ni)	1.35E+01	1.34E+01	1.32E+01	4.49E+00	4.34E+00	2.85E+00	3.68E+00	2.16E+00
Phosphorus (P)	1.13E+04	1.12E+04	1.10E+04	3.77E+03	3.64E+03	2.39E+03	3.06E+03	1.79E+03
Potassium (K)	1.16E+02	1.15E+02	1.13E+02	3.86E+01	3.90E+01	2.56E+01	4.07E+01	2.39E+01
Silicon (Si)	1.92E+04	1.90E+04	1.87E+04	6.38E+03	6.15E+03	4.03E+03	5.18E+03	3.03E+03
Silver (Ag)	5.05E+00	5.01E+00	4.93E+00	1.68E+00	1.62E+00	1.06E+00	1.37E+00	8.01E-01



Table 6. (continued).

Constituent	1							
	Mixed Tank Contents	Oxidize VOCs	Oxidize SVOCs	Oxidize Oils	Init. V-1 Rinse	Init. Stab.	Resusp. Rinse	Final Stab.
Sodium (Na)	2.99E+02	5.59E+02	5.63E+02	1.31E+05	1.27E+05	8.31E+04	1.07E+05	6.25E+04
Sulfates (SO ₄)	9.16E+01	1.11E+03	1.09E+03	5.48E+05	5.29E+05	3.47E+05	4.45E+05	2.61E+05
Zinc (Zn)	4.07E+02	4.04E+02	3.97E+02	1.36E+02	1.31E+02	8.58E+01	1.10E+02	6.46E+01
Volatile Organic Compounds	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
TCE (mean)	1.53E+00	2.92E-01	2.88E-01	3.93E-04	3.86E-04	2.53E-04	3.56E-04	2.09E-04
TCE (90% UCL)	5.60E+00	1.07E+00	1.05E+00	1.44E-03	1.39E-03	9.13E-04	1.20E-03	7.05E-04
PCE (mean)	2.31E+02	3.03E+01	2.99E+01	9.17E-02	8.84E-02	5.80E-02	7.44E-02	4.36E-02
PCE (90% UCL)	3.80E+02	5.00E+01	4.91E+01	1.51E-01	1.45E-01	9.53E-02	1.22E-01	7.17E-02
TCA (mean)	1.39E-01	2.22E-02	2.18E-02	1.57E-04	1.52E-04	9.94E-05	1.28E-04	7.52E-05
TCA (90% UCL)	3.76E-01	5.98E-02	5.89E-02	4.24E-04	4.09E-04	2.68E-04	3.45E-04	2.02E-04
Semivolatile Organic Compounds	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Aracolor-1260 (mean)	3.13E+01	3.11E+01	6.67E+00	5.06E-04	4.89E-04	3.21E-04	4.20E-04	2.46E-04
Aracolor-1260 (90% UCL)	3.72E+01	3.69E+01	7.91E+00	6.00E-04	5.79E-04	3.80E-04	4.95E-04	2.90E-04
BEHP (mean)	9.67E+02	9.59E+02	2.06E+02	2.11E-02	2.03E-02	1.33E-02	1.71E-02	1.00E-02
BEHP (90% UCL)	1.12E+03	1.11E+03	2.38E+02	2.43E-02	2.35E-02	1.54E-02	1.98E-02	1.16E-02
Radionuclides	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g
Total TRU (mean)	7.85E+00	7.78E+00	7.66E+00	2.61E+00	2.52E+00	1.65E+00	2.12E+00	1.24E+00
Total TRU (90% UCL)	8.80E+00	8.73E+00	8.59E+00	2.93E+00	2.83E+00	1.85E+00	2.38E+00	1.39E+00
Sr-90	3.33E+03	3.30E+03	3.25E+03	1.11E+03	1.07E+03	7.02E+02	9.02E+02	5.29E+02
Cs-137 (mean)	1.62E+03	1.61E+03	1.58E+03	5.40E+02	5.21E+02	3.42E+02	4.39E+02	2.57E+02
Cs-137 (90% UCL)	1.93E+03	1.92E+03	1.88E+03	6.43E+02	6.19E+02	4.06E+02	5.22E+02	3.06E+02
Other	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm

Table 6. (continued).

Constituent	1 Mixed Tank Contents	2 Oxidize VOCs	3 Oxidize SVOCs	4 Oxidize Oils	5 Init. V-I Rinse	6 Init. Stab.	7 Resusp. Rinse	8 Final Stab.
Non-Specified Carbon	2.01E+04	2.00E+04	1.97E+04	6.71E+01	6.47E+01	4.24E+01	5.45E+01	3.19E+01
Water	9.08E+05	9.05E+05	9.04E+05	2.89E+05	3.15E+05	2.06E+05	4.23E+05	2.48E+05
Process Data								
Total Mass, kg	1.71E+04	1.72E+04	1.75E+04	5.14E+04	5.32E+04	3.17E+04	3.86E+04	6.58E+04
Volume, L	1.70E+04	1.71E+04	1.74E+04	2.91E+04	3.10E+04	1.63E+04	2.50E+04	3.55E+04
Density, kg/L	1.00E+00	1.01E+00	1.01E+00	1.76E+00	1.72E+00	1.94E+00	1.54E+00	1.85E+00
CuSO4 Catalyst, kg		1.25E+01						
FeSO4.7H2O Catalyst, kg		2.91E+01						
Anti-Foam Agent, kg		3.60E+01						
HNO3 (5M), kg		4.01E-01		6.50E+00				
NaOH (50 wt% H2O), kg		1.58E+01	7.66E-01	2.14E-01	2.48E-01	5.23E-01	1.30E+00	
H2O2 Oxidant (50% H2O), kg		4.79E+01	3.39E+02					
Na2S2O8 Oxidant, kg				3.49E+04				
Stabilization Agent, kg						1.09E+04		2.72E+04

Table 7. Summary Mass Balance for the V-2/V-9 Composite Sludge Waste, During Chemical Oxidation and Stabilization Processing.

Constituent	1 2 3 4 5 6 7 8							
	Mixed Tank Contents Oxidize VOCs Oxidize SVOCs Oxidize Oils Init. V-2 Rinse Resusp. Rinse Final Stab. Tank Rinse/Slab							
Inorganics	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Aluminum (Al)	1.27E+03	1.23E+03	1.21E+03	3.33E+02	3.14E+02	2.65E+02	2.03E+02	3.90E-02
Antimony (Sb)	2.73E+00	2.64E+00	2.59E+00	7.13E-01	6.85E-01	6.12E-01	4.44E-01	8.12E-02
Arsenic (As)	7.26E-01	7.02E-01	6.90E-01	1.90E-01	1.79E-01	1.51E-01	1.16E-01	8.25E-04
Barium (Ba)	5.40E+01	5.22E+01	5.13E+01	1.41E+01	1.33E+01	1.12E+01	8.62E+00	3.56E-02
Beryllium (Be)	3.88E+00	3.75E+00	3.69E+00	1.01E+00	9.57E-01	8.08E-01	6.20E-01	6.75E-04
Cadmium (Cd) (mean)	6.63E+00	6.41E+00	6.30E+00	1.73E+00	1.63E+00	1.38E+00	1.06E+00	8.25E-04
Cadmium (Cd) (90% UCL)	8.33E+00	8.06E+00	7.92E+00	2.18E+00	2.05E+00	1.73E+00	1.33E+00	8.27E-04
Calcium (Ca)	2.78E+03	2.68E+03	2.64E+03	7.25E+02	6.87E+02	5.88E+02	4.45E+02	1.88E+01
Chlorides (Cl)	1.48E+02	4.72E+03	4.67E+03	1.58E+03	1.49E+03	1.27E+03	9.67E+02	2.86E+01
Chromium (Cr)	1.14E+03	1.10E+03	1.08E+03	2.98E+02	2.81E+02	2.37E+02	1.82E+02	2.01E-03
Iron (Fe)	6.55E+03	6.73E+03	6.62E+03	1.82E+03	1.72E+03	1.45E+03	1.11E+03	2.30E-02
Lead (Pb)	1.15E+02	1.12E+02	1.10E+02	3.02E+01	2.85E+01	2.40E+01	1.84E+01	1.89E-02
Magnesium (Mg)	3.15E+03	3.04E+03	2.99E+03	8.22E+02	7.76E+02	6.58E+02	5.03E+02	6.04E+00
Manganese (Mn)	2.36E+03	2.29E+03	2.25E+03	6.18E+02	5.83E+02	4.92E+02	3.78E+02	2.83E-01
Mercury (Hg) (mean)	3.18E+02	3.08E+02	3.03E+02	8.32E+01	7.85E+01	6.62E+01	5.09E+01	1.87E-04
Mercury (Hg) (90% UCL)	3.60E+02	3.48E+02	3.42E+02	9.41E+01	8.83E+01	7.45E+01	5.72E+01	1.88E-04
Nickel (Ni)	6.25E+01	6.05E+01	5.94E+01	1.63E+01	1.54E+01	1.30E+01	9.99E+00	6.90E-02
Phosphorus (P)	1.66E+04	1.60E+04	1.58E+04	4.34E+03	4.09E+03	3.45E+03	2.65E+03	3.14E-01
Potassium (K)	1.61E+03	1.56E+03	1.53E+03	4.21E+02	4.00E+02	3.45E+02	2.59E+02	1.86E+01
Silicon (Si)	2.82E+04	2.73E+04	2.68E+04	7.37E+03	6.95E+03	5.87E+03	4.50E+03	2.61E+00
Silver (Ag)	9.14E+01	8.84E+01	8.69E+01	2.39E+01	2.25E+01	1.90E+01	1.46E+01	4.50E-04

Table 7. (continued).

Constituent	1	2	3	4	5	6	7	8
	Mixed Tank Contents Oxidize VOCs Oxidize SVOCs Oxidize Oils Init. V-2 Rinse Resusp. Rinse Final Stab. Tank Rinse/Stab.							
Sodium (Na)	5.91E+02	3.44E+03	3.40E+03	1.13E+05	1.06E+05	8.99E+04	6.90E+04	6.17E+01
Sulfates (SO ₄)	2.73E+01	1.24E+03	1.22E+03	4.67E+05	4.41E+05	3.72E+05	2.86E+05	5.89E+00
Zinc (Zn)	2.86E+02	2.77E+02	2.72E+02	7.48E+01	7.06E+01	5.97E+01	4.57E+01	3.16E-01
Volatile Organic Compounds	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
TCE (mean)	2.36E+03	4.39E+02	4.32E+02	4.75E-01	4.48E-01	3.78E-01	2.90E-01	7.50E-05
TCE (90% UCL)	4.17E+03	7.75E+02	7.62E+02	8.38E-01	7.88E-01	6.65E-01	5.10E-01	7.50E-05
PCE (mean)	1.72E+02	2.21E+01	2.17E+01	5.38E-02	5.07E-02	4.28E-02	3.29E-02	1.87E-06
PCE (90% UCL)	1.96E+02	2.51E+01	2.47E+01	6.11E-02	5.74E-02	4.84E-02	3.72E-02	1.88E-06
TCA (mean)	2.89E+02	4.48E+01	4.41E+01	2.56E-01	2.41E-01	2.03E-01	1.56E-01	1.87E-06
TCA (90% UCL)	4.79E+02	7.42E+01	7.29E+01	4.23E-01	3.98E-01	3.36E-01	2.58E-01	1.88E-06
Semivolatile Organic Compounds	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Arachlor-1260 (mean)	3.38E+01	3.27E+01	7.01E+00	4.28E-04	4.06E-04	3.51E-04	2.63E-04	1.87E-05
Arachlor-1260 (90% UCL)	4.12E+01	3.98E+01	8.54E+00	5.22E-04	4.93E-04	4.24E-04	3.19E-04	1.88E-05
BEHP (mean)	4.94E+02	4.78E+02	1.02E+02	8.46E-03	7.98E-03	6.75E-03	5.17E-03	3.75E-05
BEHP (90% UCL)	8.20E+02	7.93E+02	1.70E+02	1.40E-02	1.32E-02	1.12E-02	8.57E-03	3.75E-05
Radionuclides	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g	nCi/g
Total TRU (mean)	7.30E+00	7.06E+00	6.94E+00	1.91E+00	1.80E+00	1.52E+00	1.17E+00	4.16E-05
Total TRU (90% UCL)	1.12E+01	1.08E+01	1.06E+01	2.92E+00	2.75E+00	2.32E+00	1.78E+00	5.05E-05
Sr-90	3.23E+03	3.12E+03	3.07E+03	8.44E+02	7.96E+02	6.74E+02	5.16E+02	4.61E+00
Cs-137 (mean)	2.08E+03	2.01E+03	1.98E+03	5.44E+02	5.13E+02	4.33E+02	3.33E+02	1.09E+00
Cs-137 (90% UCL)	2.72E+03	2.63E+03	2.58E+03	7.10E+02	6.74E+02	5.69E+02	4.37E+02	2.63E+00



Table 7. (continued).

Constituent	1							
	Mixed Tank Contents		Oxidize VOCs		Oxidize SVOCs		Oils Init. V-2 Rinse	
Other	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Non-Specified Carbon	2.52E+04	2.44E+04	2.40E+04	6.60E+01	6.22E+01	5.25E+01	4.03E+01	1.31E-02
Water	8.62E+05	8.53E+05	8.55E+05	2.85E+05	3.26E+05	4.31E+05	2.11E+05	3.75E+05
Process Data								
Total Mass, kg	8.16E+03	8.44E+03	8.59E+03	3.12E+04	3.31E+04	3.92E+04	5.11E+04	5.05E+03
Volume, L	8.01E+03	8.23E+03	8.38E+03	1.76E+04	1.95E+04	2.57E+04	2.65E+04	3.11E+03
Density, kg/L	1.02E+00	1.03E+00	1.03E+00	1.77E+00	1.69E+00	1.53E+00	1.93E+00	1.63E+00
CuSO4 Catalyst, kg		7.28E+00						
FeSO4.7H2O Catalyst, kg		1.70E+01						
Anti-Foam Agent, kg		1.69E+01						
HNO3 (5M), kg		1.91E-01		3.97E+00				
NaOH (50 wt% H2O), kg		8.43E+01	4.52E-01	2.07E+01	8.64E-02		8.64E-01	1.51E-01
H2O2 Oxidant (50% H2O), kg		1.62E+02	1.65E+02					
Na2S2O8 Oxidant, kg				2.11E+04				
Added Water, kg				2.14E+03				
Stabilization Agent, kg							1.80E+04	3.15E+03

3.3.3 Batch Size

For control purposes, the chemical oxidation process shall be performed in small batches, rather than in two large batches of each of the composite V-Tank wastes. Performing the chemical oxidation process in batches allows for more control over the process, and less impacts associated with process upsets, should they happen. Performing the process in batches also allows for smaller process and off-gas equipment to be used. Table 8 shows the total number of batches for each sludge composite.

As shown in Table 8, each waste tank composite has different size batches (88.5-gal specified for batches from the V-2/V-9 consolidated wastes, and 116 gal specified for batches from the V-1/V-3 consolidated wastes). The different batch sizes were based on a desire to keep all final batch sizes at or near 200 gal, after the chemical oxidation processes have been completed. This is needed to size the 500-gal reaction vessels for both consolidated tank volumes (allowing a surge volume potential within each reaction vessel of around 150%, at all times).

The V-2/V-9 initial batch volume is smaller than the V-1/V-3 initial batch volumes because the V-2/V-9 batches have higher concentrations of organic components in them than the V-1/V-3 batches. To keep the sodium persulfate concentration below the water concentration in the V-2/V-9 batches, it will be necessary to add approximately 23 gal of additional water to each V-2/V-9 batch. The increased volume associated with this water addition accounts for most of the volume difference, with differences in chemical oxidant additions accounting for the residual differences. According to calculations, the final volume of each V-1/V-3 and V-2/V-9 batch, after chemical oxidation, is 203-gal and 199-gal, respectively.

Table 8. Total number of batches and batch information for each composite sludge.

	V-2/V-9 Sludge Composite	V-1/V-3 Sludge Composite
Total Number of Batches	24	39
Initial Batch Size	88.5 gal	116 gal
Rate of Peroxide Addition	264.5 ml/min	264.5 ml/min
Time for 40°C Peroxide Addition	21 min	4 min
Time for 80°C Peroxide Addition	21 min	27 min
Maximum Heat of Reaction During Peroxide Addition	35.2 kW	25.2 kW
Volume After Peroxide Addition	91.5 gal	118 gal
Rate of Persulfate Addition	1.6 kg/min	1.6 kg/min
Time for 80°C Persulfate Addition	550 min	559 min
Maximum Heat of Reaction During Persulfate Addition	35.2 kW	35.4 kW
Volume After Persulfate Addition	199 gal	203 gal

3.3.4 Batch Processing

Each batch of composite sludge will undergo the following operational steps.

1. Fill the reaction vessel with the desired volume of sludge waste.
2. Add the desired amount of ferrous sulfate and copper sulfate catalysts, along with the desired volume of anti-foaming agent. Adjust the solution to a pH of 4, using the necessary amount of 5 M HNO₃.
3. Heat the batch to a temperature of 40°C.
4. Add 50 wt% hydrogen peroxide to the batch at a rate of 265 ml/min, until all of the VOCs (TCE, PCE, and TCA) in the batch have been oxidized (as indicated by at-line gas chromatography/mass spectrometry [GC/MS] analysis). Maintain a pH of 3-5 throughout this addition period, using periodic additions of 50 wt% NaOH, as necessary. In addition, provide intermittent cooling of the reaction vessel, as necessary (up to 40 kW) to keep the batch temperature at 40°C.
5. Heat the batch to a temperature of 80°C.
6. Add 50 wt% hydrogen peroxide to the batch at a rate of 265 ml/min, until all of the PCBs and BEHP in the batch have been oxidized (as indicated by on-line ion chromatography analysis of the inorganic chloride concentration in the batch, and/or at line GC/MS analysis of the PCBs and BEHP). Maintain a pH of 3-5 throughout this addition period, using periodic additions of 50 wt% NaOH, as necessary. In addition, provide intermittent cooling of the reaction vessel, as necessary (up to 40 kW) to keep the batch temperature at 80°C.
7. Adjust the pH of the solution to 3, using the necessary amount of 5 M HNO₃. Then add dry sodium persulfate to the batch at a rate of 1.6 kg/min, until all of the organics in the batch have been oxidized (as indicated by CO₂ analysis of the off-gas). Maintain a pH of 3-4 throughout this addition period using periodic additions of 50 wt% NaOH, as necessary. Also, provide intermittent cooling, as necessary (up to 40 kW) to keep the batch temperature at 80°C and add ~90 L of water to each V-2/V-9 batch, throughout the sodium persulfate period, at a rate of ~162 ml/min, to maintain the peak sodium persulfate levels below the level of water in the tank.
8. Neutralize the chemically-oxidized batch to a pH of at least 7. Then cool the chemically oxidized batch to 20°C, using a chiller. Agitation will be maintained during this cooling period.
9. Pump the chemically oxidized batch out of the reaction vessel, and into the appropriate V-Tank.

Figure 9 is a process flow diagram that shows the chemical oxidation process.

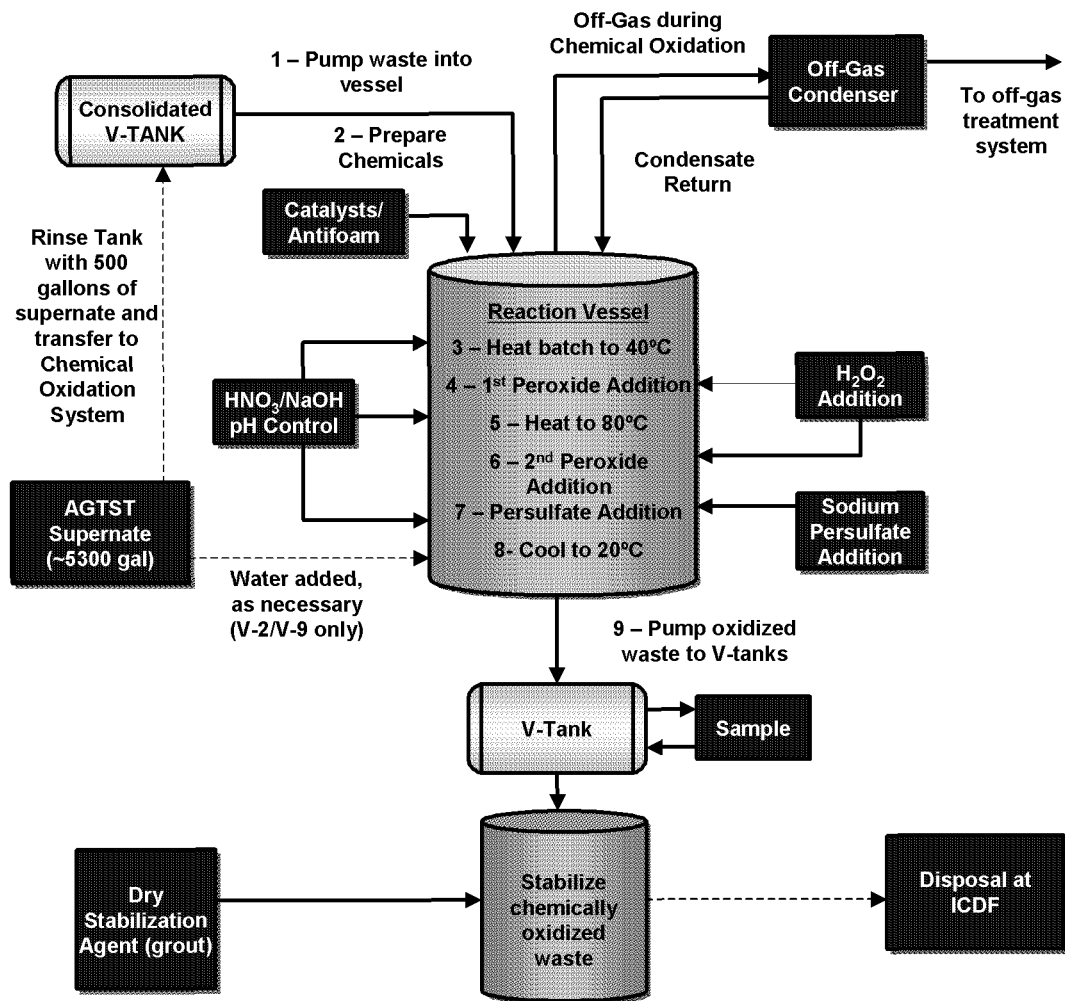


Figure 9. Process flow diagram of the Chemical Oxidation Process.

A summary of the projected times for each step of the V-2/V-9 and V-1/V-3 batch campaigns is shown in Table 9.

Table 9. Projected Time Durations for Each Batch Step, During the V-2/V-9 and V-1/V-3 Chemical Oxidation Campaigns

Batch Step	V-2/V-9 Campaign	V-1/V-3 Campaign
1. Pump Waste into Vessel	18 min	23 min
2. Chemical Preparation Step	30 min	30 min
3. Heat Batch to 40°C	11 min	14 min
4. 1 st Peroxide Addition (Destroy VOCs)	21 min	4 min
5. Heat to 80°C	23 min	27 min
6. 2 nd Peroxide Addition (Destroy BEHP, PCBs)	21 min	27 min

Batch Step	V-2/V-9 Campaign	V-1/V-3 Campaign
7. Persulfate Addition (Destroy Oil, Organic Residues)	550 min	559 min
8. Cool to 20°C	654 min	659 min
9. Pump to V-Tanks	40 min	41 min
Batch Time for Steps 4-7 (Oxidation)	615 min (10.3 hr)	617 min (10.3 hr)
Batch Time for Steps 8, 9, and 1-3 (Cooling/Preheating)	753 min (12.5 hr)	767 min (12.8 hr)
Process Control Analyses (Samples are taken and analyzed during cooling and do not affect total batch time).		
CO ₂	Real Time	Real Time
Volatile	30 min	30 min
Chloride	30 min	30 min
PCB	30-45 min	30-45 min

To minimize the time necessary to treat all the V-Tank waste, two reaction vessels will be operated at the same during the chemical oxidation process. To eliminate the need for a second off-gas system, operation of the reaction vessels will be staggered so that only one vessel will be oxidizing waste at any given time. One vessel will be performing steps 4-7 (oxidation) while the other vessel performs steps 8, 9, and 1-3 (cooling/preheating). Cooling/preheating takes up to 2.5 hours longer to complete than oxidation, requiring the batch campaign undergoing oxidation (steps 4-7) to wait until the waste in the other reaction vessel has completed the cooling/preheating process to begin the next step (see Figure 10).

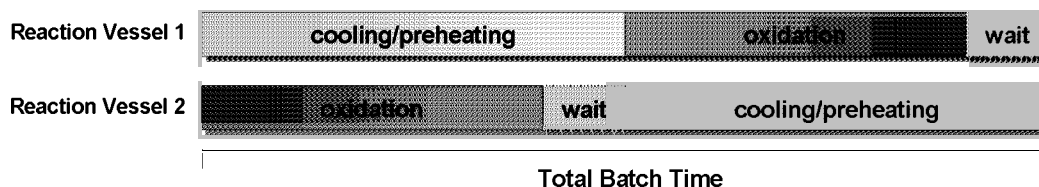


Figure 10. The two reaction vessels will be operated in a staggered arrangement, only one vessel will be oxidizing at any given time.

Staggering the oxidation and cooling/preheating times results in a total campaign period of 311 hrs (13.0 days) for the V-2/V-9 campaign, and 509 hrs (21.2 days) for the V-1/V-3 campaign. Adding 14 days for supernate and tank homogenization operations, and an additional 11 days for stabilization time, flushing, and equipment maintenance, the total time associated with chemical oxidation and stabilization of the V-Tanks is under 60 24-hr days. Using a 24-hour, 7-day work week, the entire process will be completed in ~8.5 weeks. Under a 24-hr, 5-day work week, the entire process will take 13 weeks.

The oxidized waste will undergo chemical analysis to determine if the oxidation process was successful. Analyses will be performed on each batch while operations personnel are waiting for the solution to cool to 20°C, before discharging the batch back to the V-Tank.

3.3.5 Chemical Analysis

3.3.5.1 RCRA Analyses

The INTEC Analytical Laboratories will be utilized to perform the analyses to meet the RCRA characterization needs for VOC, SVOC, metal, and other constituents. Typical turnaround times for these types of analyses are 40 days. Due to the expected oil contamination in these samples, the analysis of the PCB and the BEHP will be challenging to quantify; the oil will follow the analytes and cause interferences. Due to the high concentration of solids, the samples for analyses for metals and chlorides will have to be separated and analyzed in two fractions, with a 24 hr leach required on the solid fraction.

3.3.5.2 Process Control Analyses

The oxidation process will be followed in real time.

- **CO₂ Analysis:** The generation of CO₂ will be monitored continuously, and the results plotted by an on-line CO₂ monitor. CO₂ is released during oxidation. A decrease in CO₂ indicates a decrease in oxidation.
- **Oxygen analysis:** The generation of oxygen, during chemical oxidation, will also be monitored continuously, with the results plotted via an on-line O₂ monitor. Use of an oxygen analyzer, in combination with the CO₂ analyzer, will permit a real-time evaluation of reagent efficiency and hydrogen peroxide decomposition vs. organic oxidation rate. It will also be useful in preventing the build-up of excessive hydrogen peroxide concentrations, which could bring about runaway chemical oxidation rates, with loss of temperature control.
- **Volatile Analysis:** Process analysis for the volatile analytes of TCE, PCE, and TCA will be performed using a small gas chromatograph at the project location. Filtering the sample prior to injection will eliminate the solids, and leave only oil. A backup instrument will be used to ensure process continuity.
- **Chloride Analysis:** Process analysis for chlorides for monitoring PCB destruction will be accomplished by an ion chromatograph. A sample will be filtered and directly injected into an ion chromatograph to determine chloride. This analysis will take approximately 30 minutes per sample after instrument setup and calibration. The potential for the oil in the sample to cause contamination of the column is a risk, however this risk will be reduced significantly with the use of a “guard” column that is replaced frequently. The guard column is a short ion exchange column that is used as a sacrificial column to protect the main ion exchange column.
- **PCB Analysis:** Analysis for PCB will be accomplished at the job site by the use of a go-no-go test that is specific for PCB. This test uses disposable sample preparation/extraction tubes, with prepackaged reagents. Actual measurement uses a colorimeter that is small and portable. Typical go-no-go limits are 1ppm or 10ppm PCB. The detection determination of the sample is above or below standard levels, but does not quantitate the result. The procedure results can be determined in 30 to 45 minutes.

3.3.5.3 Waste Issues

The analysis will generate laboratory mixed waste in the form of analytical residues and analytical containers. Since the samples originate from a known PCB stream, all of the waste will have to be considered as PCB contaminated or rinsed to meet decontamination standards in 40 CFR 761.79.

3.3.6 Batch Consolidation, Sampling, and Retrieval

After each batch has been oxidized, it will be returned to one of the V-Tanks in a manner that reconsolidates the chemically oxidized contents of the V-1/V-3 and V-2/V-9 consolidated sludges. The chemically oxidized batches from V-1/V-3 will be discharged to tank V-3, while the oxidized batches from V-2/V-9 will be discharged to tank V-1. This reconsolidation provides a means for unshielded storage of the chemically oxidized wastes while they undergo the confirmatory sampling and analysis necessary to verify that they can be stabilized in a manner that meets the land disposal restrictions (LDR) and waste acceptance criteria (WAC) for final disposal at the ICDF. To assist in this effort, each chemically oxidized batch will be analyzed using a gas chromatograph/mass spectrometer prior to being discharged back to the V-tanks. This initial sampling verifies that the hazardous organic levels in each batch are low enough that minimal stabilization of the resulting batch would meet the LDRs and WAC for final disposal at the ICDF, if stabilized separately.

As shown in Table 8, the final volume of each V-1/V-3 batch is expected to be 203 gal, while the final volume of each V-2/V-9 batch is expected to be 199 gal. With an estimate of 39 V-1/V-3 batches, and 24 V-2/V-9 batches, and 500 gal of rinsate for both consolidated tank volumes, the final volume of chemically-oxidized waste expected to reside in Tank V-3 (V-1/V-3 waste) and Tank V-1 (V-2/V-9 waste) is expected to be 8417 gal and 5276 gal, respectively. Final confirmatory analysis is expected to take less than 30 days after each tank consolidation effort. The chemically oxidized and consolidated waste materials will be analyzed for F001 listed organic concentrations, TCLP metals, characteristically hazardous organics, and underlying hazardous constituents (UHCs).

To provide regulatory representative sampling of each consolidated tank, each individual batch will require sampling and analysis prior to consolidation. To reduce these individual sampling costs, it may be possible to re-suspend each tank's consolidated sediments, and mix them in with the liquid materials, to provide a well-mixed, near homogenous slurry within each tank. This re-suspension effort using the MFPJMS needs further investigation. The potential problem with re-suspension is the resultant density of the chemically oxidized waste in each underground V-tank may exceed the pumping head capacity available to re-suspend and mix the tank wastes. Based on calculations performed using the assumed chemically oxidized waste densities and resultant waste volumes for V-1/V-3 (discharged to Tank V-3) and V-2/V-9 (discharged to Tank V-1), it appears that there is sufficient head capacity for re-suspending the contents of V-1/V-3, but the possibility of suspending the contents of V-2/V-9 is marginal. A possible solution would be to lower the MFPJMS several feet below grade to allow for sufficient head capacity for V-2/V-9.

Once the confirmatory sampling has been completed, the consolidated waste materials from Tank V-3 can then be again re-suspended and pumped to a grout mixer, where it will be mixed with sufficient grout material to produce a stabilized waste form. Approximately 3400 gallons of re-suspended waste will then be pumped out of Tank V-3.

Once the 5000-gallon level is reached in Tank V-3, an additional 1617 gal (3234 gal total) of supernate from the AGTST will be added to both Tank V-3 (containing the residual chemically-oxidized waste from V-1/V-3) and Tank V-1 (containing the chemically-oxidized waste from V-2/V-9). The purpose of these supernate additions to the oxidized waste sludges is to allow for MFJPMS re-suspension efforts, during pumping, as long as possible. The added supernate additions reduce the densities of the residual waste volumes, thereby increasing head capacities. Furthermore, the addition of these supernate volumes to each oxidized sludge does not violate regulatory concerns, since confirmatory sampling was performed in advance of the liquid addition, and the GAC-filtered V-3 supernate was already shown to have met the more stringent waste-water guidelines. In essence, the addition of the supernate was used to combine waste streams in a manner beneficial to implementation of the grouting operation. Pumping of the residual waste from Tank V-3, and all of the waste from Tank V-1 can then be continued.

Based on calculations, the addition of 1617 gallon of V-3 supernate to each 5000-gal waste stream will allow for MFJPMS re-suspension activities to continue until a waste volume of 2300 gal is reached in each tank (after approximately 4300 gal will be removed from each tank). Final removal of the 2300-gal residual will waste volume will then need to be performed by inserting a Moyno grout pump up to 2 ft down into the manway of each tank. The final pumping operations will need to be performed without continual re-suspension by the MFPJMS system. As a result, a fundamental assumption, associated with this final operation, is that the Moyno pumping operation can be performed quickly enough that no additional tank re-suspension efforts will have to be concurrently in place. If later testing indicates that such an assumption is not valid, there may be the need for additional grade excavation needed, to lower the MFJPMS pumping skid to a depth sufficient to guarantee mixing. This assumption will be addressed in title design.

Following waste stabilization operations, the 500-gallons of reserved V-3 supernate will be used to rinse out the contents of each tank (250-gal per tank), with the dilute rinsate pumped out of the tank (via a Moyno or peristaltic pump) and sent to the grout mixer for stabilization. Performing the stabilization activities in this manner minimizes waste volume, by using the supernatant material for final cleanup (i.e., no additional water will be needed).

3.3.7 Corrosion

Corrosion was investigated for the material selection of the reaction vessels. The oxidation process will occur at an acidic pH and an elevated temperature to optimize the performance of the oxidizing agents. Table 10 and Table 11 provide operating conditions and concentrations of significant constituents affecting the corrosivity of the waste during and following the oxidation process. Table 10 provides data for the oxidation of the V-1/V-3 waste composite, while Table 11 provides data for the oxidation of the V-2/V-9 waste composite. Oxidation of the chlorinated organic compounds will result in an increase in the solution chloride concentration. Chlorides cause pitting and stress cracking of stainless steel. The corrosivity of solutions containing chlorides increases with chloride concentration and temperature.

Table 10. Constituents in V-1/V-3 composite waste affecting stainless steel corrosion rate.

	Prior to Oxidation	After VOC Oxidation	After SVOC Oxidation	After Oil Oxidation ^a
Cl, ppm	122	526	537	206
Cr, ppm (assumed Cr ³⁺)	244	242	238	81.3
Fe, ppm (assumed Fe ³⁺)	3950	4260	4190	1430
Hg, ppm (assumed oxidized to HgO)	58	57.5	56.6	19.3
HNO ₃ , mol/L	0	1.02E-04	1.02E-04	9.67E-04
pH	~7	3-5	3-5	3-4
Temperature (°C)	ambient	40	80	80
fate of stream following step	remain in reaction vessel	remain in reaction vessel	remain in reaction vessel	neutralize, cool to 20°C, and transfer back to tank

a. Following oxidation, concentrations are reduced due to the increase in batch volume associated with oxidizing agent addition.

Table 11. Constituents in V-2/V-9 composite waste affecting stainless steel corrosion rate.

	Prior to Oxidation	After VOC Oxidation	After SVOC Oxidation	After Oil Oxidation ^a
Cl, ppm	148	4720	4670	1580
Cr, ppm (assumed Cr ³⁺)	1140	1110	1080	298
Fe, ppm (assumed Fe ³⁺)	6550	6730	6620	1820
Hg, ppm (assumed oxidized to HgO)	318	308	303	83.2
HNO ₃ , mol/L	0	1.01E-04	1.01E-04	9.76E-04
pH	~7	3-5	3-5	3-4
Temperature (°C)	ambient	40	80	80
fate of stream following step	remain in reaction vessel	remain in reaction vessel	remain in reaction vessel	neutralize, cool to 20°C, and transfer back to tank

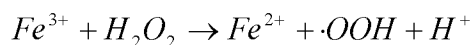
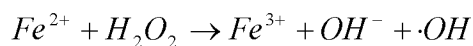
a. Following oxidation, concentrations are reduced due to the increase in batch volume associated with oxidizing agent addition.

The low pH, elevated temperature, and high chloride concentration in the reactor vessel would likely lead to corrosive failure of a stainless steel reaction vessel. Therefore, a glass lined reaction vessel was chosen for processing the V-Tank waste. The integrity of glass lining is very important in preventing corrosion to the steel casing. Care must be taken to ensure that the glass lining is not fractured upon installation of the reactor vessel or during the cyclic batch heating and cooling operations occurring

during the processing campaign. It is assumed that fluorides are not present in the waste in sufficient quantities to corrode the glass lining of the reactor vessel.

Following oxidation of the V-Tank waste in the reaction vessel, the oxidized waste will be returned to the stainless steel V-Tanks for collection and storage prior to stabilization. It is assumed that the V-Tanks will enter the processing campaign from a non-corroded state. As previously mentioned, the concentration of chlorides in the oxidized waste will be significantly higher than in the untreated waste as a result of oxidation of the chlorinated organic compounds.

The Fenton's Reagent oxidizing agent identified for use in the oxidation process may contribute to vessel corrosion concerns. The iron catalyst added to the waste during processing will alternate between the +2 and +3 oxidation states:



In the presence of chlorides, iron in the +3 oxidation state increases the waste corrosivity. Iron in the +2 oxidation state does not present nearly the corrosion issue. The iron content in the waste was assumed to be in the +3 oxidation state to ensure corrosion predictions were as conservative as possible.

The presence of mercury can reduce the corrosive characteristics of a chloride containing solution by binding up chlorides through the formation of Hg_2Cl_2 . However, in the oxidized V-Tank waste the mercury is assumed to all be oxidized to HgO , rendering it unavailable for reduction of the corrosive chloride waste content.

The presence of nitrates can reduce the rate of chloride attack on stainless steel by passivating the stainless surface. However, the nitrate concentration in the V-Tank waste is not high enough to reduce chloride attack of the stainless steel to an appreciable degree.

Cooling the oxidized waste to approximately 20°C prior to transferring from the glass lined reaction vessel back into the below grade stainless steel V-Tanks is an essential step towards reducing the risk of corrosion related failure. It is assumed that the exothermic heat of reaction from residual oxidation reactions taking place in the waste following oxidation in the reactor and transfer back to the V-Tanks for storage prior to stabilization will not increase the temperature of the waste above the ~15°C below-grade temperature. In addition, adjustment of the oxidized waste to a neutral pH would increase the safety margin from corrosive failure of the V-Tanks.

Storage of oxidized waste in the stainless steel V-Tanks for a duration of 3 months at below grade soil temperatures could result in some pitting of the tanks. However, the extent of pitting would not result in failure of the tanks in a 3 month period. Storage of oxidized waste in the stainless steel V-Tanks for 12-15 months would be a higher risk activity. Although it is predicted that corrosion induced failure of the tanks would not occur in 12-15 months, the probability of failure is significantly greater than for a 3 month storage period. The probability of corrosion induced failure of the stainless steel V-Tanks from oxidized V-2/V-9 composite waste is greater than that of failure from oxidized V-1/V-3 waste composite.

Corrosion testing should be completed to verify corrosion predictions, which are based primarily on experience and observations of INEEL personnel³.

3.3.8 Grout Formulation

Several grout formulations have been identified as having potential for stabilization of the oxidized V-Tank waste. These include grout formulations based on Portland cement with supplemental mineral admixtures, 100% alkali-activated slag, and a reformulation of a proprietary cementitious grout developed by Technology Visions.

The baseline grout formulation is a mixture of 20 wt% Type V Portland cement and 80 wt% blast furnace slag. This formulation is expected to provide good leachability resistance, good free-liquid binding capability, and good resistance to sulfate attack. This grout formulation can also be modified to include higher or lower percentages of mineral admixtures to optimize conformity with the stabilization requirements. Long term testing is necessary to fully evaluate how various grout formulations will perform over time. Testing will also be required to determine the sulfate compositional limitations in the oxidized waste that cannot be exceeded in order to meet the stabilization requirements.

3.4 Mechanical Design

In order to perform ES-CO/R/S on the V-Tank waste a variety of mechanical systems need to be integrated. These include:

- A waste removal system for transferring the waste between the V-Tanks, the reaction vessels, and the grout/stabilization system
- A treatment system to perform chemical oxidation
- A grout/stabilization system to stabilize the oxidized waste in disposal containers
- An off gas system to treat the off gas from the chemical oxidation process
- A control system to monitor system performance and log data parameters.

Each of these systems, along with fail safe design considerations, maintenance requirements, and system test and checkout requirements are detailed in this section.

³ Personal telephone communication between B.C. Norby, and D. S. Wendt (both of Bechtel BWXT Idaho LLC) March 27 2003 and April 24, 2003.

3.4.1 Waste Removal System

The sludge removal system will consist of the Mobile Fluidic Jet Pulse Mixing System, peristaltic pumps, and a Moyno grout pump. Each of these pieces of equipment is detailed below.

3.4.1.1 Mobile Fluidic Jet Pulse Mixing System

A MFJPMS will be used for mixing and removing tank contents (see Figure 11). AEA Technologies manufactures this type of system and is a possible provider for the V-Tanks project. The AEA MFJPMS was used as the basis for design decisions contingent on the mixing system specifications. This system is a proprietary pumping and mixing system and comes as a complete unit on a three skids. The MFJPMS will be used to mix the tank contents as uniformly as possible before removal from the tanks as well as product transfers between V-Tanks, from V-Tanks to reaction vessels, and from V-Tanks to grout mixer for grouting and stabilization. The MFJPMS will also be used to rinse each tank, ensuring that all waste contents will be oxidized.

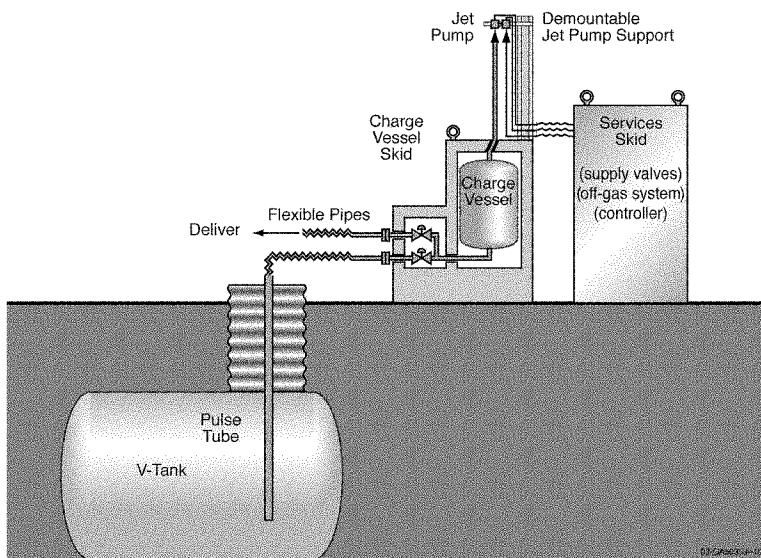


Figure 11. The fluidic pulse jet mixing System will be used to remove the sludge from the V-Tanks

The pulse jet pump system mixes the sludge and supernate via a three phase mixing process:

- Suction phase
- Drive phase
- Vent phase.

During the suction phase, the jet pump is used to create a partial vacuum in the charge vessel which in turn draws liquid up from the storage tank into the vessel.

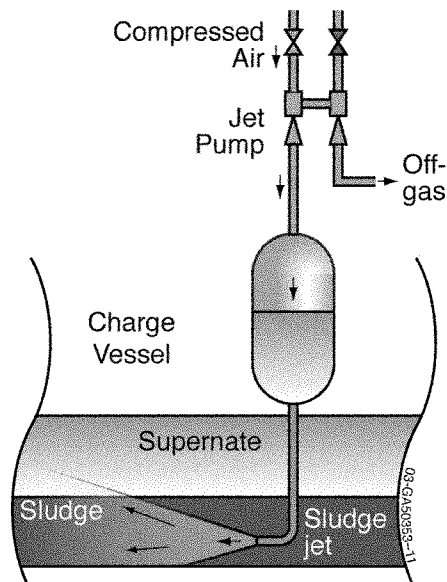


Figure 12. The drive phase of the sludge removal process.

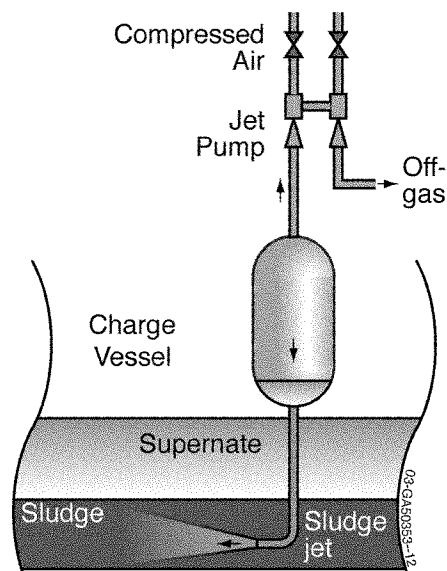


Figure 13. The vent phase of the sludge removal process.

Once the charge vessel has been filled with the liquid, the jet pump pressurizes the charge vessel, which drives the liquid back into the V-Tank, agitating the contents of the tank and re-suspending settled solid particulates into the supernate. This is known as the drive phase (see Figure 12).

When the charge vessel is almost empty, the compressed air is shut off to prevent pressurized air from being forced back into the V-Tank. A vent is opened which allows the remaining liquid in the charge vessel to drain back into the V-Tank. This is referred to as the vent phase (see Figure 13).

In order to keep the contents agitated, these three phases are repeated, and the V-Tank contents (supernate/sludge mixture) is transferred back and forth between the charge vessel and the tank.

The MFJPMS will mix the tank contents as uniformly as possible before removal and will be used for all product transfers between V-Tanks, and from the V-Tanks to the reaction vessels and the AGTST. The MFJPMS will also be used to re-suspend the waste in the oxidized waste in the tanks and pump it to the grout/stabilization system.

3.4.1.2 Peristaltic Pump

The Peristaltic pump used to remove the residual liquid from the sump area of the V-Tanks and the 6,000 gallons of supernate from V-3 will be the Watson-Marlow SPX 40 High-Pressure Hose Pump. This pump has a suction head capability of 28 feet (at ambient atmospheric pressure at TAN assuming the liquid temperature is about 50° F), which is more than adequate for the required 18' to 19' needed to place the pump at ground level. This is a positive displacement pump so the discharge pressure will only be what the system requires up to 232 psi. Because of the design of a peristaltic hose pump, no draining of the hose contents back into the tank, thus disturbing the sludge, will occur. The pump can operate dry

without damage if flow becomes restricted. Watson-Marlow guarantees the pinching of the hose in the pump will function as well or better than a check valve. The pump shall be mounted on a skid with drip pan for secondary containment. Power required for operation is 115/230 V single phase or 230/460 or 575 V three phase.

The peristaltic pump will pump the supernate from V-3 into the AGTST. This supernate will be held in reserve and used in various ways during the treatment of the V-Tank waste. A diffuser will be used to remove the liquid without entraining the sludge (INEEL 2003d).

The suction hose on the peristaltic pump will be a 2" Spiralite-115 (or equivalent). The Spiralite-115 will prevent the hose from collapsing during pumping operations. Discharge hose will be 2" Buna N (or equivalent). All hoses and fittings will be poly sleeved (i.e., Bartlett Services, Inc. Super Sleever) to meet the requirement for double containment.

3.4.1.3 *Moyno Grout Pump*

A Moyno Grout Pump will be used for moving the oxidized waste from the reaction vessels back to the V-Tanks and the residual oxidized waste from the bottom of V-Tanks (that can't be pumped by the MFJPMS) to the grout system. The Moyno® L-Frame series positive displacement pump is designed specifically for moving material similar to the oxidized V-Tank waste. This pump handles viscosities over 1,000,000 cps, solids up to 1 inch in diameter and has a high suction lift of up to 28 feet.

3.4.2 Chemical Oxidation Treatment System

The treatment system will consist of two 500-gallon working capacity reaction vessels and a chemical addition system. The MFJPMS will be used to transfer batches of V-Tank waste to the reaction vessels. The two reaction vessels will be placed in parallel but will be used to accomplish different steps in the oxidation process (see section 3.3.4).

The contents of Tank V-3 will be treated first. The MFJPMS will be used to mix the sludge in V-3 as uniformly as possible and transfer batches to the reaction vessels. Varying amounts of additives will be added to the waste at predetermined rates. The chemical oxidant addition system will be capable of adding 50 wt% of hydrogen peroxide at a rate of 265 ml/min, and dry sodium persulfate at a rate of 1.6 kg/min. Total batch size, with all additives included, will be 199-203 gallons.

Conductive foam level monitors will monitor the level of foam in the reaction vessels during chemical oxidation. If the level of foam is excessive, the rate of addition for the oxidizing agents will be slowed down to decrease the level of foam.

The reaction vessel contents will be continually agitated to maintain uniformity while the reaction takes place. The agitator will be capable of sufficiently agitating a waste stream containing sediments and 28.5 wt% water, with a density of up to 1.77 gm/ml, such that adequate chemical oxidation rates occur.

The vessel contents will also be heated via an integrated electric heating/cooling module to temperatures ranging from 20°C to 100°C. A steam or electrical heating system will be capable of supplying 150 kW of heat to one of the reaction vessels. In addition, each reaction vessel will be designed to allow for up to 40 kW of simultaneous cooling to be supplied to each reaction vessel at all times. The 40kW cooling capacity is needed to maintain a constant reaction vessel temperature during chemical oxidation. Without such temperature control, raises to the reaction vessel temperature would accelerate

the rate of chemical oxidation, causing even greater temperature increases (and reaction rates) than even a 40 kW cooling system is capable of handling (potentially resulting in a runaway reaction). 40 kW cooling of each reaction vessel (via an 80-kW chiller) is needed to allow the oxidized waste in one reaction vessel to cool, while waste contents in the other reaction vessel are chemically oxidized.

The reaction will be allowed to proceed while being monitored until it is determined the reaction has run its course. Once the tanks are empty, they will be rinsed using supernate from the AGTST. Following rinsing, the supernate will undergo the same treatment process as the V-Tank waste.

3.4.3 Grout/Stabilization System

Once verification has been received that the V-Tank waste has been successfully oxidized, the waste will be mixed with grout and placed in storage containers. The main grout constituents have been identified as Portland Cement Type 5 (20%) and Blast Furnace Slag (80%). Figure 14 shows the stabilization process.

The MFJPMs will pump the treated waste from the V-Tanks to a ribbon mill cement mixer where the grout will be added and mixed with the waste. This grouted mixture will then be poured into an ICDF acceptable disposal container. The selection of which container will require coordination with packaging and transportation personnel and Waste Generator Services to ensure the container meets to Department of Transportation requirements and ICDF Complex Waste Acceptance Criteria (DOE-ID 2002). The disposal container selected will be a 550-gallon high-density polyethylene container (e.g. Peabody Engineering 550-gallon Polyethylene Tank). The 550-gallon high-density polyethylene container must be capable of meeting any expansive stresses associated with stabilizing the waste.

The grout will be received in bulk from a local supplier and will be pre-mixed. This grout will then be transferred to the Ribbon Mill via a flexible screw conveyor(s) such as those supplied by Flexicon Corporation. The poly containers will be mounted on a forklift skid so it can be moved into place for filling and then located

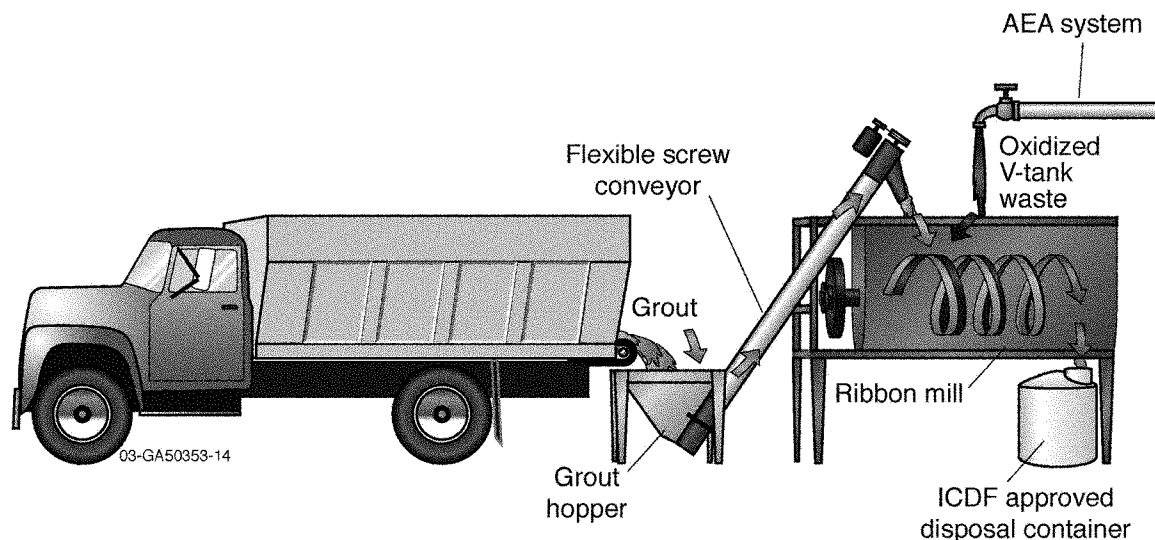


Figure 14. The V-Tank waste will be stabilized with grout and sent to the ICDF for disposal.

in a staging area with secondary containment provided to await solidification and final disposition prior to being transported to the ICDF for disposal.

3.4.4 Off Gas System

The V-Tank contents contain VOCs, radioactive components, mercury, and mercury compounds. During the chemical oxidation process some of these constituents, in small amounts, could potentially be entrained in the process off gas stream. To protect the workers and environment from the above-mentioned constituents, they will be removed from the off gas and captured for proper disposal. The off-gas system will also be connected to each of the TSF-09 tanks (V-1, V-2, and V-3) via the 3 in. vent line on each tank. This will cause air to flow into the tanks and through the off gas system. Figure 15 is a visual representation of the off gas treatment process.

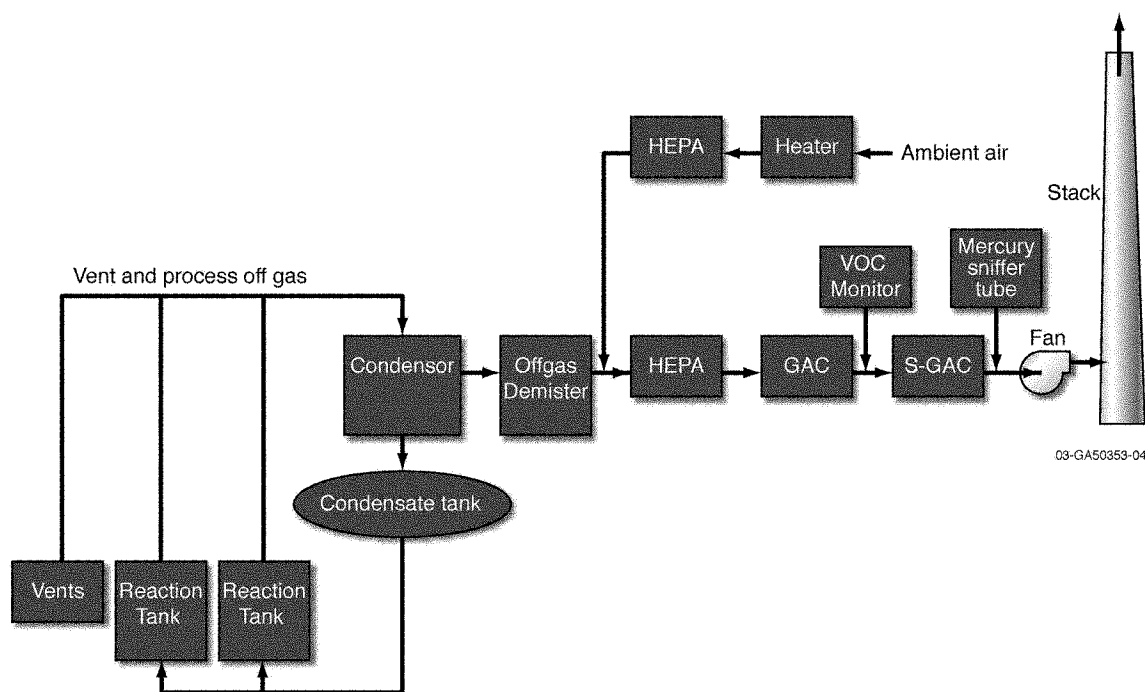


Figure 15. The off gas from the V-Tanks and MFJPMs undergoes a treatment process before being released into the atmosphere.

Off gas from the reaction vessel, fluidic pulse jet mixing vents, and V-Tank vents will be cycled into a condenser. The condenser will separate the water vapor and any droplets that may be present from the off gas and collect the condensate in a condensate tank where it will be recycled back into the reaction vessel.

Off gas that is not condensed and recycled back into the reaction tank flows through a treatment process before being released into the atmosphere. This treatment process begins with a demister that removes any mist droplets from the process gas stream. The demister will contain a fiber mesh for the mist elimination element. After passing through the demister, the process gas flow mixes with bleed-in air

derived from ambient (outside) air. The bleed-in air is temperature controlled by a heater and a HEPA filter is used to provide a backflow system boundary for radioactive confinement.

Once the off gas stream has mixed with the ambient air, the composite stream runs through a HEPA filter bank (consisting of a low-grade filter followed by a HEPA filter) to trap submicron particulate from the composite stream. Following the HEPA filter, the composite gas stream runs through a GAC bed that will absorb VOCs contained in the gas stream. The stream will be sampled for VOCs once it has passed through the GAC bed. This sampling is necessary to determine that the VOCs have been oxidized and also to indicate when the GAC bed is no longer effective and must be replaced. Used GAC beds will be disposed of at an off-site disposal facility.

Following the VOC monitor, the gas stream passes through a sulfur-impregnated granular activated carbon (S-GAC) bed. The S-GAC serves to absorb the small amount of mercury emissions released to the off-gas system that are not recondensed at 5°C, while also acting as a back-up GAC bed, in the event of organic breakthrough through the primary GAC bed, before the off-gas system is switched to the parallel GAC bed. Calculations performed in support of the uncontrolled release of off-gases indicate that even uncontained releases of mercury, at the system operating temperatures, are below the regulatory levels. Therefore, there is no regulatory driver for an S-GAC bed to capture uncondensed mercury vapors. Nevertheless, use of an S-GAC bed eliminates the need for expensive continuous mercury monitoring to verify that mercury emissions are below regulatory levels. Instead of continuous mercury monitoring, the off-gas will be periodically sampled for mercury, using Drager tubes. Used S-GAC beds will be disposed of at an off-site disposal facility if the bed experiences VOC breakthrough.

3.4.5 Control/Data Logger System

A control system will monitor system performance and log data parameters. Certain aspects of the waste treatment (Heaters, coolers, off gas bleed in air, etc.) will be controlled remotely by the control system. The extent to which the control system controls operations will be determined during the next stage of project development.

The control and data recording system will require a Programmable Logic Controller (PLC) similar to an Allen Bradley Control Logix system. The control system shall require a wide range of control, I/O and communications options, with distributed I/O capability to allow for the placement of I/O modules on individual equipment skids or on remotely located equipment. The control system will require the following:

- Industrial-hardened hardware
- Modular I/O with analog, digital, PID, and network communication modules.
- Distributed I/O capability
- Removal and insertion of I/O modules under power
- Module replacement without disturbing I/O wiring
- Multiple network communication protocols including Ethernet
- Provide multiple programming language editors (relay ladder, structured test, and functional block diagram).

A minimum of two operator screens will be required to display the system operating parameters, control valve line-up, off-gas system parameters, alarms, and system status.

3.4.6 Fail Safe Design Considerations

In the event of power failure or activation of an emergency-stop master relay, system power will be lost. Waste transfer and chemical makeup stream valves will be fail-safe normally-closed valves to ensure uncontrolled chemical reactant mixing or siphoning does not occur. If loss of system power occurred during a material transfer operation, use of fail-safe normally-closed valves would ensure that unregulated material transfer did not occur.

If loss of system power occurred while chemical oxidation takes place, addition of reactants and processing additives to the reaction vessel would cease. Unreacted material already in the reaction vessel would continue to react, potentially increasing the temperature of the reaction vessel contents no longer subject to heat exchange with cool reaction vessel jacket heat transfer fluid. Consequently, a 200-gallon water-filled quench tank with a fail-safe normally-open valve will be positioned above each reaction vessel. In the event of power loss, the valves will open and 200 gallons of water will flow into each reaction vessel, simultaneously cooling and diluting the reactants to slow the chemical oxidation reactions.

Residual reactions occurring in the quenched reactants may continue to emit carbon dioxide, oxygen, water vapor, mercury, and VOCs. A fail-safe normally-closed off gas inlet slipstream configuration in the form of a back draft damper will be included in future design phases to prevent mercury and VOCs from exiting the process via the inlet slipstream under unforced gas flow conditions. Particulate matter, VOCs, and mercury migrating into the off gas treatment train will continue to be captured by the HEPA filters and GAC beds, respectively. Since there will be no off gas condensing capacity in the event of power loss, water vapor from the reaction vessel will migrate to and accumulate on the HEPA filters resulting in an increased pressure drop. HEPA filter bypass ducting with check valves will allow off gas to be routed around wetted HEPA filters to the GAC beds once the system pressure begins to put excessive pressure on the off gas inlet slipstream back draft damper. Performing chemical addition operations such that excessive quantities of oxidizing agents are not present in the reaction vessel at any given time will minimize the hazards associated with system power loss.

3.4.7 Maintenance Requirements

The system will be designed to be assembled in components. The ES-CO/R/S operation is expected to take two to three months and occur during the summer. Preventative maintenance is anticipated that would include tasks such as adjustments on pumps and seals, as well as measurement and control equipment. An established preventative maintenance program will be used to accomplish all preventative maintenance. Breakdown and repair work will be accomplished by pre-anticipated and pre-approved work orders to the extent possible. Emerging work will also be accomplished by the work order process and completed on a case-by-case basis. Trained and qualified craftsmen will perform maintenance.

3.4.8 System Test and Checkout Requirements

The system will be designed assembled and tested in an off-site location (not necessarily off of the INEEL). This will be done to prepare procedures, provide operator and maintenance training and provide

adequate checkout, testing and operation of the equipment prior to final operation. This strategy is necessary to make the operation, process, and manpower utilization efficient and economical. System checkout will follow approved and controlled procedures and processes. The actual oxidation process will be carried out only to the extent possible to maintain a safe work environment.

All system and component tests shall comply with the following INEEL management control procedures (MCPs):

- MCP-550 Software Management
- MCP-3056 Test Control
- MCP-3630 Computer Change Control
- MCP-9217 Design Verification

Component checkouts will be performed on a per component basis to assure all components are working as expected and meet their functional requirements. These checkouts can be done before or after the components are integrated into the system.

All instrument sensors and the data acquisition equipment will be calibrated prior to waste treatment. Calibration will be performed using existing TAN calibration procedures.

Control of all variable speed pump drives will be tested and calibrated to verify proper flow control.

3.4.8.1 *Qualification Test*

A system qualification test shall be performed prior to on site system assembly and SO testing. The qualification test shall include as much of the system equipment as is reasonably possible. Surrogate waste and reagents shall be acceptable for test purposes. This test shall be used for design verification of the system control and data recording requirements. If all the components are available, operator training could take place subsequent to completion of the test. A qualification test is used to verify design but is generally not the sole design verification.

3.4.8.2 *System Operability Test*

A System Operability (SO) test shall be performed on the control and data acquisition parts of the system prior to delivery and customer turnover. All or any other parts of the system may be SO tested at this time. Trained operations personnel could be used to perform this test as part of operational training on the system.

3.4.8.3 *Integrated Test*

A system integrated test (or a trial run using water) of the complete system shall take place on site prior to customer turnover.